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CRITERIA AND METHODS FOR ASSESSMENT OF

CARCASS AND MEAT CHARACTERISTICS

IN BEEF PRODUCTION EXPERIMENTS

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CRITERIA AND METHODS FOR ASSESSMENT OF CARCASS AND MEAT CHARACTERISTICS IN BEEF PRODUCTION EXPERIMENTS

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Seminar on Carcass and Meat Quality
in the EEC Programme of co-ordination
of research on beef production

organized by

Research Institute for Animal Husbandry "Schoonoord"
Driebergseweg 10d, Zeist
THE NETHERLANDS

November 9th - 12th 1975

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PREFACE

This publication contains the proceedings of a seminar held in the Netherlands on November 9-12, 1975 under the auspices of the Commission of the European Communities, as part of the EEC programme of co-ordination of research on beef production.

The programme was drawn up by a scientific working group on "Carcass and Meat quality" on behalf of the Beef Production Committee. The working group comprised Ir. H. de Boer (Chairman), Netherlands; Professor A. Romita, Italy; Professor L. Schön, Germany (Fed. Rep.); Dr. R.W. Pomeroy, United Kingdom, and in the planning of the seminar they were joined by Mr. R. Jarrige, France; Dr. J.C. Tayler (temporarily seconded to the CEC during 1975 from the Grassland Research Institute, Hurley, Maidenhead, Berkshire, United Kingdom) and Mr. P. l'Hermite, C.E.C.

The subject chosen for this seminar was drawn from the list of priorities in research objectives drawn up in 1973 by members of a Committee (now the standing Committee on Agricultural Research, CPRA) in the form given in Appendix I. One of the functions of this series of seminars was to summarise and update the information available on the selected subjects and to discuss future needs for research, so as to assist the Commission in evaluating the probable impact of research on agricultural production within the Community.

The Commission wishes to thank those representatives of the member States who took responsibility in the organisation and conduct of this seminar; notably Ir. H. de Boer (Chairman), Miss Ir. D.H. van Adrichem Boogaert (Local organiser); and the Director of the Research Institute for Animal Husbandry "Schoonoord" for providing the facilities of the Institute.
Thanks are also accorded to the chairmen of session 1 to 6, respectively, Mr. C. Béranger; Professor E. Kallweit; Mr. B.L. Dumont; Mr. A. Cuthbertson; Dr. Lis Buchter and Ir. H. de Boer.

CONTENTS

OBJECTIVES AND BACKGROUND OF THE SEMINAR

The objective of this seminar was to review critically the assessments which could usefully be made at the end of experiments of different kinds, to encourage greater uniformity in methods of assessment and establish suitable reference methods; and to consider the impact of carcass aspects on experimental design.

There is great diversity in the assessment made at slaughter and thereafter, resulting from the application of different criteria as well as from the use of different methods for similar assessments. Part of the diversity may be justified by different experimental objectives; some, however, cannot be explained in this way. These differences limit the comparability and universal interpretation of experimental results, and this is particularly important in the case of long-term and expensive experimentation with cattle. It therefore seems appropriate to have these differences in methods discussed by those involved in research in different countries, in order to achieve more comparability and uniformity in experiments on beef production and selection.

Carcass and meat aspects constitute the final part of beef production experiments and the assessments are essential for a complete evaluation. On the other hand, these assessments also affect the experimental design, particularly the end point of the experiment when a choice has to be made of the weight, age or "finish" at slaughter. Three topics were therefore included in the seminar:

- Carcass assessment in relation to experimental design;
- Live animal and carcass assessments;
- Economic interpretation of carcass and meat assessments.

APPENDIX

RESEARCH OBJECTIVES DRAWN UP BY THE BEEF PRODUCTION COMMITTEE, June 1973, AND LIST OF SEMINARS PROPOSED IN 1975-1976 ON SELECTED TOPICS

Research objective	SEMINAR	PLACE	DATE
I. To obtain a greater number of viable calves through: 1. better control of reproduction: - interval between calvings; - heat synchronisation; - sex determination; - production of twins; - egg transplantation.	Egg transplantation	Cambridge	Dec. 10,11,12,1975
2. a reduction in calf mortality during and after birth	Perinatal ill-health in calves	Compton	Sept. 22,23,24,1975
3. early breeding and the use of once bred heifers for slaughter	The early calving of heifers and its impact on beef production	Copenhagen	June 4,5,6,1975
II. To improve quality of meat and increase the weight of the carcass through a better understanding of the genetic, physiological and nutritional factors influencing body development	Improving nutritional efficiency of beef production	Theix	Oct. 14,15,16,17,1975
To improve the utilisation of the carcass by technological means	Criteria and methods for assessment of carcass and meat characteristics in beef production experiments	Zeist	Nov. 10,11,12,1975
III. To achieve a better understanding possibly by co-operative programmes of the comparative suitability of the major cattle breeds used as pure breeds or in crossing (including beef and dairy breeds) for: - fertility - ease of calving - maternal ability - growth - characteristics of carcass meat - feed utilisation	Optimization of cattle breeding schemes	Dublin	Nov. 26,27,28,1975
	Cross-breeding experiments and strategy of breed utilisation to increase beef production	Verden	Feb. 9,10,11,1976

Close co-operation was recommended with the agencies studying the economics of beef production and possibly special studies integrating biological and economic approaches with a view to improving the balance between milk and beef within the Community

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Part 1

CARCASS ASSESSMENT IN RELATION TO EXPERIMENTAL DESIGN

EEC Seminar on Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments, Zeist, 1975.

THE IMPACT OF CARCASS AND MEAT ASPECTS ON EXPERIMENTAL DESIGN, PARTICULARLY IN RELATION TO FEEDING LEVELS AND TIME OF SLAUGHTER

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ABSTRACT

An attempt is made to list and briefly discuss the animal growth, carcass composition, feeding level and experimental design factors which interest and need to be taken into consideration in designing beef production experiments. The advantage of serial slaughtering and the problem of carcass dissection costs are also discussed.

RESEARCH OBJECTIVES

The aim of beef research should be to provide information for planning within the meat production, processing and marketing industry on how muscle of quality can be most efficiently produced, slaughtered, cut and marketed. It is important to take this overall view when designing experiments, as optimum efficiency in one part of the chain may not lead to optimum efficiency overall. The solution which provides the optimum answer in one part of the industry may not lead to the best overall solution.

WHEN TO SLAUGHTER?

Slaughter can be arranged on the basis of: -

- Constant estimated finish (fatness)
- Constant age
- Constant liveweight
- Liveweight as a proportion of mature weight or calf weight

Constant finish

Estimating the finish or fatness of animals used to be a very subjective measurement with a large experimental error, particularly due to variation between operators, which made it an unsuitable method of terminating an experiment. The use of ultrasonic measurement should take a lot of guesswork out of this measurement and make it much more acceptable as a means of terminating an experiment than it has been up to now. However, even if one can measure finish fairly accurately, the level of finish has to be decided upon and this has to be related to market requirements. Do we know these requirements ? Do they change from market to market ?

Constant age

Slaughter at a constant age has a number of attractions. There is no error involved in the measurement. One knows the date of slaughter well in advance and can plan accordingly. It can be a useful basis on which to slaughter animals in breed comparison trials when the plane of nutrition of the animals throughout life has been under control. However, if the animals are fed on grassland, variations in feed available within season and from season to season may lead to considerable differences in liveweight at constant age and make it an unsuitable method of terminating such experiments.

Constant liveweight

Slaughter at a constant liveweight entails frequent weighing of animals and the experimenter has only limited warning of the date of slaughter. In some feeding experiments it may be necessary to slaughter at a constant liveweight, for example in cases where different planes of nutrition are imposed during part of the lifetime of the animal. In these cases the experimenter may need to know how much extra feed and time will be needed to reach a certain finish or liveweight and he will not be able to do this if animals are slaughtered on an age basis.

Liveweight as a percentage of mature weight or birth weight

In some breed comparisons it may be desirable to slaughter at a liveweight which is proportional to mature liveweight (Taylor, 1963) on the assumption that the animals will be slaughtered at equal physiological development. For the same reasons it may be equally valid to slaughter at a liveweight which is proportional to birthweight (Roy, 1967). It is much easier to get birthweight for breeds than mature liveweight.

Slaughtering at equal physiological development could be a useful method of terminating experiments in breed comparisons involving lifetime feed efficiency studies.

SERIAL SLAUGHTERING

Fat percentage in the carcass increases and feed efficiency decreases with increase in carcass weight. Breed interacts with these on account of variations in rate of physiological development. Furthermore, cost of slaughter and cutting the carcass per kilogram carcass weight decreases with increasing slaughter weight. Finally, cross-sectional area of any cut presented to the consumer will increase with increasing slaughter weight. Because of these it is very desirable to consider slaughtering animals serially so that the interactions can be measured adequately. There needs to be a wide spread in the slaughtering weights (or age) because a slaughter weight which does not look attractive at a particular time because of poor feed efficiency may become attractive due to an increase in the cost of calves, slaughtering and cutting costs, or the willingness (or otherwise) of the consumer to pay a premium for joints of a certain dimension.

NUMBER OF ANIMALS

The real problem with serial slaughtering is - will it increase the number of animals required on the experiment ? In serial slaughtering experiments the results can be analysed by regression, and the information on one slaughter point is added to by information from the other slaughter points. Because of this, no large increase in numbers should be necessary for the main comparison. However, if important interactions occur, and there is need to measure them as accurately as the main differences, then a considerable increase in numbers may be necessary.

CARCASS DATA

Serial slaughtering can provide very useful and interesting carcass data on the marketing of beef. Take, for instance, muscularity of the carcass. That is, the thickness of the muscle in relation to the dimensions of the skeleton. Muscularity influences the cross-sectional area of muscles and consumer cuts. These are also influenced by carcass weight. With serial slaughtering, the interactions between muscularity, carcass weight, and consumer cut cross-sectional area, can be very usefully studied and may answer the marketing question. Will an increase in carcass weight increase the cross-sectional area of consumer joints so as to compensate for lack of muscularity in a carcass ? If it does, what other characteristics of the consumer joint are still lacking due to lack of muscularity ?

PRE-EXPERIMENTAL SLAUGHTER GROUPS

In some management and feeding experiments, only the latter part of the lifetime performance of the animal may be studied and the decision has to be made as to whether a group of animals will have to be slaughtered at the start of the experiment to provide data on carcass weight and composition. A pre-experimental slaughter group is not always necessary if relative data for the treatment comparisons are all that is needed. In these experiments the experimental groups are randomly selected from a population and the validity of the experiment is based on the fact that there is no significant difference between the groups at the start of the experiment. Any difference in carcass weight or composition at the end of the experimental period can be attributed to the experimental treatments and valid relative feed efficiencies compared. Of course these relative feed efficiencies cannot be validly compared with results from other experiments.

KILLING OUT PERCENTAGE

The error involved in measuring killing out, or dressing percentage (carcass weight/liveweight) can be high, due to variation in gut fill. In planning experiments special precautions may have to be taken so that gut fills, when recording the liveweight, are realistic. Time of weighing in relation to last feed, availability of drinking water, and quiet handling of the animal during the weighing operation are important.

As a measurement, killing out percentage is of value to a farmer who can sell his animals by liveweight or deadweight and wishes to compare prices. In beef experiments, the measurement is of little value and can be replaced by more accurate measurement. For instance, it is far better to compare animals on the basis of carcass weight and offal weight than use killing out percentage to measure differences in offal weights.

If feed efficiency is measured as feed divided by liveweight gain, there can be considerable error in the measurement due to variation in gut fill, and gut fill can vary throughout the experiment and be related to the digestibility of the feed. Killing out percentage obtained at the end of the experiment will not allow one to make adjustment to feed efficiency measures during the experiment.

CARCASS EVALUATION COSTS IN PERSPECTIVE

Dissection work can be expensive. Useful information can be lost if the research worker is unable to get the money to cover the cost of dissecting the carcasses from his experiments. This often occurs because there is confusion about the distribution of the cost of his experiment. The real costs up to the time the carcass is produced can be as much as ten times the commercial value of the carcass, when one allows for the salary of the experimenter, the technician's salary, the stockman's salary, the cost of experimental land, housing, equipment and overheads. On the other hand, the cost of dissecting a half carcass may not be a lot greater than the value of the half carcass. However, in many people's minds the cost of the experiment is often erroneously equated to the commercial cost of producing the animal, which is about equal to the value of the animal. They then think that the cost of dissection will increase the cost of the experiment by 50%, when in fact, if the true cost of producing the animal is calculated, the cost of dissection will only increase the cost of the experiment by as little as 10%. The result is that the money is not made available for dissection and the most valuable results for the experiment are not obtained.

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GENERAL REVIEW OF ASSESSMENTS WHICH COULD USEFULLY BE MADE AT THE END OF BEEF PRODUCTION EXPERIMENTS, IN RELATION TO THE OBJECTIVE OF THE EXPERIMENT.

by B.L. DUMONT, Laboratoire de recherches sur la viande, Institut National de la Recherche Agronomique, Centre National de recherches zootechniques, 78350 JOUY-EN-JOSAS, FRANCE.

Abstract

Beef production experiments may have various biological or economic goals, studying the effect of factors inherent in animals (age, sex, breed ...) or external to animals (feeding, environment ...) on meat production. A very large number of traits could theoretically be considered, but only a limited number of characteristics may be practically judged due to many difficulties. The need for uniform carcass assessment and meat quality appraisal - both in quantitative terms - is emphasized. For that purpose research workers of different countries must agree in common methods of appraisal and sampling.

Introduction

It is not a simple matter to determine the results of beef production experiments. The overall judgment is very complex, involving a number of economically and genetically very different traits such as

- growth rate,
- feed efficiency,
- carcass characteristics
- meat and fat quality ...

We don't need to emphasize the importance of production traits. It is obvious that consideration of the consumption of different feeds given to animals during growth and fattening enables us to know the cost of feeding and thus to appreciate the return of meat production from plant production (cereals and pastures). It is probably more difficult to decide on the importance of carcass traits. These traits are in such number that it is not surprising that few or no calculations of their relative economic importance and genetic variability can be cited. Nevertheless a very large number of characters may be and must be used to define the bovine carcass. In Table I is given a list - probably provisional - of the traits which are known, at the moment, to affect variation in carcass and meat quality. Only an accurate and detailed assessment of these characters would allow the real appraisal of the products to be obtained at the end of a production experiment.

Common experience shows that the assessment made by most authors considers only a few - often very few - of the characters which might be observed. This situation may be explained by at least two reasons:

1. Production experiments are very rarely made to describe totally the production and the products;
2. Assessments of some of the more interesting criteria are expensive, time-consuming and are complex for the majority of research workers to attempt routinely.

<u>Different types of production experiments</u>

Beef production experiments may have various goals and are thus conducted according to various experimental procedures:

First we must consider that the number of factors to be studied is very large:

- some are *inherent in animals*: age, sex, breed, weight;
- others are *external to animals*: feeding (level of nutrition, types of feed) or environment (climate, housing ...).

Second, the aim of the experiments may be either a biological or an economic one.

Table I. Carcass and meat characteristics

	Carcass weight			
	Carcass composition			
	- % muscle			
	- % bone			
	- % fatty tissue	: kidney		
		: external		
		: intermuscular		
	- muscle distribution			
CARCASS	- fat distribution			
	- weight (and % of the side) of cuts	: primal cuts		
		: retail cuts	: untrimmed	
			: trimmed	
	- anatomical composition of cuts			
	Carcass conformation			
	- general conformation			
	- measurements			

Table I (continued)

MEAT

Histological variables

- Number of muscle fibres
- Fibre size
- Amount and distribution of connective tissue : collagen
  : elastin
- Muscle innervation
- Metabolic type of muscle fibre
  (enzyme profile)

Chemical components

- Dry matter content
- N content
  . N total
  . N myofibrillar
  . N sarcoplasmic
  . N stroma - amount of hydroxyproline
  . Myoglobin content - haem iron
- Lipids
  . Crude fat
  . % fatty acids
  . Phospholipids
- Minerals
  . Ash content
  . K, Na, Mg

Physico-chemical parameters

- pH value
- water holding capacity : cooking and frying loss
- transmission value
  (sarcoplasmic proteins)
- connective tissue
  : cross linking of collagen
  : salt soluble collagen
  : acid soluble collagen
  : alkaline soluble collagen
  : mechanical properties of collagen fibre : tensile strenght
  : swelling
- rheological properties : shear forces
- colour definition
  : brightness
  : lightness
  : purity
- colour stability : metmyoglobin reducing ability

* When it is considered on a *biological* basis the production experiment is performed to study the influence of one of the production factors we mentioned above on the biological characteristics of the animals. In such "biological" experiment the results of the trials are expressed, quantitatively, by the values of the following live animal variables:

  - weight
  - rate of growth
  - feed intake
  - body measurements.

  Carcass traits may also be included among the biological variables which are to be measured in "biological" experiments.

* When the trial is an *economic* study, the treatment effect is essentially, if not only, considered in terms of costs, prices, input and output. The price per kg carcass is then very important. It may also be interesting to know the grades awarded to the carcasses (e.g. in the official grading system of the country).

The variables to measure when defining or describing the product largely depend on the type of factors which are studied in each production experiment.

a. *external factors*

1. The study of the influence of *one* factor of this type is generally conducted so that all the internal factors are made as uniform as possible (the animals studied are of the same breed, sex; they have similar weights at the beginning of the experiment and have the same origin ...)

2. Of all the characteristics which are measured we deal first, if not solely, with those which are the more variable and those which are directly influenced by the factor studied.

Feeding experiments are current examples of such production experiments where the effects of one external factor are studied. In these experiments it is usual to consider:

rate of growth
feed conversion } of the live animal

anatomical composition
(especially amount of fat) } of the carcass

Characteristics of the carcass other than its composition (carcass measurements or conformation for example) are not generally considered because they are less affected by the production factors and their measurement is not very interesting. Meat characteristics are seldom considered in the feeding experiments. One can suggest that it might be important to know the amount of the intramuscular chemical fat (and its composition) which is related to tenderness and flavour of meat.

b. *internal factors inherent in animals*

In trials where the effects of the internal factors are studied (with no consideration of the interaction between genetic and external factors), we may recommend:

1. Standardisation of the production conditions (especially feeding);
2. The measurement of the largest possible number of the characteristics quoted in Table I and relative to the composition and conformation of the carcasses, and to meat quality.

It is clear from the literature that both composition and conformation of bovine carcasses are largely influenced by weight, sex and breed of the animals. Their influence on meat quality is often thought to be of minor importance, mainly because up to now the effects of breed differences on the detailed quality profile of beef have not been thoroughly explored.

Problems involved in measurements

Many methods have been proposed to assess or to measure the various important carcass and meat characteristics. They will be described and discussed in detail by the different participants at this meeting. They will not be stated here, but we just want to make some general remarks about them.

1. The measurement of the various characteristics is spaced over time; they depend upon the slaughtering process, the storage conditions of the carcass; some of them are mutually exclusive (e.g. meat quality assessments); their costs are very variable.

For all these reasons it is obvious that in one beef production experiment it will not be possible to measure all the carcass traits or the meat traits quoted in Table I. It is necessary to select traits which are, or seem to be, the most important.

2. The degree of interest in any measurement should be considered in relation to its accuracy and its cost.

All destructive methods,

- either completely destructive methods, such as chemical analysis or physical analysis of texture,
- or partly destructive methods, such as dissection,

are expensive and therefore relatively prohibitive. In fact, we must consider that their cost has to be appreciated not in absolute value but with respect to the total amount of expenses previously incurred during the experiment.

What CARROLL (1972) said about dissection is true for many other measurements:

"In many people's minds the cost of the experiment is often erroneously equated to the commercial cost of producing the animal, which is roughly equal to the value of the animal. They then think that the cost of dissection will increase the cost of the experiment by from 50 to 100 % rather than 10 to 20 %. The result is that the extra money is not made available and the real results of the experiment are not obtained."

3. Unfortunately the number of methods of assessment does not become stable with time, which creates a problem in reference methods. Not only is the list of interesting characteristics continuously increasing with the advance of scientific knowledge, but, even for one character, methods develop and change sometimes anarchically.

4. To judge meat quality factors it is necessary not only to standardize conditions of storage and preparation of the meat samples but also to solve the problem of sampling. It becomes more and more evident that in order to judge meat quality of the carcass (consisting of two hundred muscles) it is insufficient to consider a limited number of muscles.

Final remarks

All these remarks must help to determine in each type of beef production experiment the characteristics to measure in order to judge efficiently the biological or economic effects of production factors.

Final choice by the research worker of the characteristics to assess is a process which is his own, according to his aim and his means.

Means at the disposal of research workers may often be insufficient to allow various and detailed measurements, namely for meat quality measurements.

A variety of measurements is not necessarily advantageous because it is detrimental to the comparability of the results obtained by different research workers.

Adhesion of research workers in animal production to common and uniform methods is highly recommended.

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DISCUSSION ON SESSION 1 ON "CARCASS ASSESSMENT IN RELATION TO EXPERIMENTAL DESIGN"
Discussion leader: C. Béranger.

General Discussion

Pomeroy: "Eating quality" is missing from D u m o n t's list of characteristics, but is a most essential one.

Dumont agreed, but considers international agreement on its assessment impossible in view of its subjectivity and the divergency of cooking habits.

Pomeroy agreed, but thinks its repercussion on butchery methods should be kept in mind.

The discussion leader wanted to focus the discussion first on s e r i a l s l a u g h t e r i n g.

De Boer suggested the principle could overcome difficulties in choosing the end-point on the basis of finish.

Bech Andersen, speaking from experience, considered serial slaughtering and extrapolation of characteristics most useful. Three successive slaughtering points are the necessary minimum.

Béranger pointed to the fact that regressions may differ between breeds and weight ranges.

Carroll considered live weight ranges of great importance, the more because they are not the same for different markets. Serial slaughterings are of greatest importance in major experiments, in which the range should be broad so as to explore the possibilities.

The discussion leader raised as a second point the r e l a t i v e c o s t s of measurement and wondered whether a general recommendation could be made for a better planning of facilities and means for this purpose.

Hardwick emphasized the importance of criteria which reflect the appreciation of the user and the consumer. Apart from that the assessments to be done should be related to the questions to be answered, and costs are only secondary.

Kallweit did not consider a general recommendation relevant, in view of diverging experimental situations.

Pomeroy pointed once more to the fact that the real costs of experiments are easily 10 times the value of the animal. This should not be overlooked in choosing a cheaper alternative for complete dissection, which may be less effective. This point met with *others*'approval, who stressed that high costs are inherent in

particular to meat research.
Béranger concluded that in the next sessions on individual characteristics the question of justification of measurements would be considered in more detail. He proposed to follow in the next sessions some kind of a c h e c k l i s t for arriving at distinct conclusions. This checklist, as proposed by *De Boer*, dealt with the following points:

1. The accuracy, ease of application, costs and further standardization of the methods involved.
2. The relevance of methods in experiments of different kind, e.g. on
   - breed comparison, crossing and selection
   - feeding and management systems
   - nutrition, growth and efficiency
   - classification and grading.
3. Further activities considered necessary to improve comparability of experimental results and co-ordinated design of future experiments.

These points remained on the blackboard throughout all further sessions.

Part 2

ASSESSMENTS IN THE LIVE ANIMAL

EEC Seminar on Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments, Zeist, 1975.

LIVE WEIGHT MEASUREMENT

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A B S T R A C T

Problems in the measurement of live weight are discussed in this paper. The importance of the weight of the digestive contents is shown. It represents 10 to 20 %. of the live weight according to the diet. The percentage also varies with the animals's age and with the timė since the last meal.

Therefore it is suggested that weight comparisons should be made only for feeding systems of the same type. The date of weighing should be chosen in relation to dietary changes. The time of weighing is discussed : at pasture in relation to the time of day and the method of grazing ; in the stable in relation to meals.

The changes in live weight with time can be formulated in various ways. A number of equations are proposed which permit calculation of live weight at any time during the period considered.

I N T R O D U C T I O N

The growth of an animal can be defined as its increase in weight with time. Thus, all studies requiring knowledge of animal growth rates (comparison of breeds or of feeding systems) must include measurement of live weight at a given moment of time and of weight gain over a given period of time.

Comparison of weights or of weight gains implies that these have the same significance for the different periods considered. This is not always true, for the live weight of cattle depends on the digestive contents. These vary widely (from 10 to 20 % of the live weight) according to the feeding system, age and time since the last meal.

- VARIATIONS IN THE WEIGHT OF THE DIGESTIVE CONTENTS

1/ With the type of rations

The weight of the digestive contents depends essentially on the digestibility and the rate of transit of the food. A study by BERANGER *et* al (unpublished) showed (table 1) that the proportion of digestive contents in the whole body, was very high (21 %) when the animals received poor quality grass hay ad libitum, but much lower (5 % less of body weight) when 4 kg of barley were added to the ration. When animals were fed good quality lucerne hay the digestive contents were smaller (17 or 18 %) than with grass hay, although the dry matter intake was higher. The addition of concentrates or of beet pulp to this hay also caused a 3 to 5 % reduction in the proportion of live weight made up by the digestive contents.

When grass or kale were fed, the weight of digestive contents was lower than with hay, although there were wide variations.

The measurement of live weight thus has a different significance according to the feeding system. In particular, the variations in weight of digestive contents are such that the weight of an animal receiving hay in the stable cannot be compared with that of the same animal a few days later, at pasture.

2/ With animal age

The variations in the proportion of digestive contents in the live weight with aging of the animal are simply indications of changes in feeding system. According to MATHIEU (1961) the weight of digestive contents represents only 3 % of the live weight at birth and remains constant in veal calves. However, in weaned calves, the rumen developes rapidly and the digestive contents make up 10 % of the live weight at 2 months of age and 13 % at 5 months. After weaning the proportion of digestive contents in the whole body depends on the feeding system, and thus the type of production ; it does not vary with the age or the weight of the animal. Thus, measurement of live weight before and after weaning does not have the same meaning. The live weight gain of a veal calf cannot be compared with that of a weaned calf. It is, therefore, important to define precisely the date of weaning in order to make the best interpretation of weight changes.

Table 1 VARIATION IN THE WEIGHT OF THE GUT CONTENTS (AS A PROPORTION OF THE LIVE WEIGHT) FOR DIFFERENT DIETS

(BERANGER et al, unpublished data)

Diet	Coefficient of digestibility			Animals			Gut content weight as % live weight at slaughter
	Organic matter	Crude protein	Crude fibre	Type	Number	Live weight	
Grass hay	55.7	46.7	58.1	cows	15	549	21.11
Grass hay + barley	65.3	58.5	56.9	oxen	15	576	16.32
Lucerne hay	58.6	73.5	36.6	cows	28	545	17.88
Lucerne hay + concentrate	-	-	-	oxen	8	505	12.42
Lucerne hay + fodder beet	72.6	65.5	52.8	oxen	12	549	14.32
Fresh Rye-grass	75.5	63.5	74.5	cows	10	587	13.41
Kales	-	-	-	oxen	15	531	13.52

3/ With the time since the last meal

As the time since the last meal increases, the live weight of the animal decreases, due to reduction in the digestive contents. However, this loss of weight varies according to the feeding system (fig. 1).

Thus, when animals receive low or medium digestibility diets, of slow transit (hay), the relative weight of digestive contents changes very little. In contrast, when animals receive highly digestible diets, of rapid transit (kale, grass) there is a considerable reduction (4 - 5 % in 10 h). An animal of 500 kg at pasture, thus loses 20 to 25 kg in 10 hours of fasting, most during the first 5 hours.

- CONSEQUENCE OF THESE VARIATIONS ON THE METHOD OF WEIGHT DETERMINATION

1/ At pasture

When animals are put out to pasture after overwintering indoors there is a considerable weight loss and then a very noticeable gain which finally stabilises. This is due to the change in diet and the occurence of diarrhoea when grazing young grass. Eight to 10 days adaptation are necessary before the first live weight measurement can be made.

During the period of pasture the live weight varies with the time of day and the grazing system.

The weight of digestive contents varies with the intake. BERANGER et al. (unpublished data) observed variations of 10 to 17 kg between weight in the evening and in the morning. In addition the animal pasturing cycles depend on day length. Therefore, it appears advisable to regulate the time of weighing with that of sunrise, so that the animals have always had one grazing cycle.

In free grazing the weight variations depend on uncontrolable factors (temperature, humidity, etc) but in strip grazing the animals overfeed the first day when they enter a new strip. It is in these conditions that the weight of digestive contents is least variable and most satisfactory for comparison of weight gains between different cycles of grass growth.

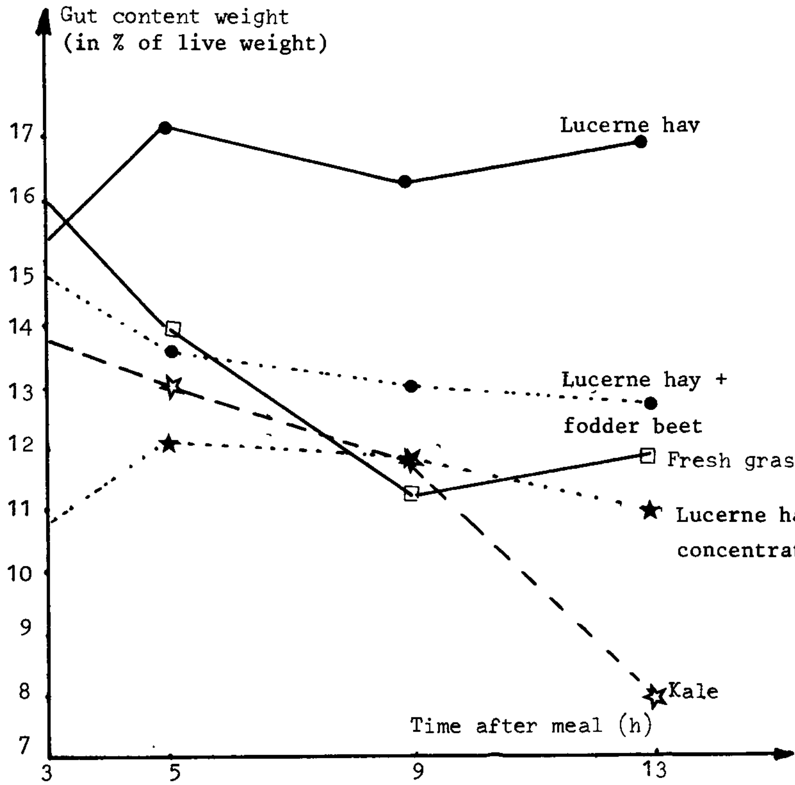

Fig. 1 CHANGES IN THE WEIGHT OF THE GUT CONTENTS, (AS A PROPORTION OF LIVE WEIGHT), WITH TIME AFTER FEEDING, FOR DIFFERENT DIETS (BERANGER et al., unpublished data)

The measurement of live weight during the grazing season should thus be made after one grazing cycle on the animals' first day in a new strip.

2/ Indoors

Comparisons of live weights, and thus of weight gains can be made only if the feeding systems are similar. When the animals are brought in from pasture and receive an overwinter diet of roughage or silage, it is necessary to wait for two or three weeks while the weight of digestive contents becomes stabilized, before any measurements can be made. This is also true for any change in the feeding system during the period of zero grazing.

Since the weight of the digestive contents varies during the day, according to the time since the last meal, all the animals in one experiment should be weighed the same time after a meal and in the same order. The reduction in weight of the digestive contents varies with the feeding system. In order to minimise differences between diets weights should be taken immediatly after meals. Alternatively animals could be weighed after a period of fasting if the number of hours and the facility to drink is determined. However, if several different rations are given during the day it is preferable to weigh the animals full, after one particular meal.

To increase the precision in the measurement of live weight at certain particular periods (beginning or end of an allowance of a given diet, weight at a given age) weights can be measured for two or three days consecutively, at the same time of day. This system would also detect variations in weight due to excessive water consumption before weighing or to stressing of the animal.

3/ Growth curve and live weight gain determination

When animals receive a given diet during the same period of feeding, regular measurements of live weight permit a growth curve to be drawn. In order to reduce daily variations in gut content and to calculate live weight at any moment during the period considered, it may be necessary to introduce values measured at different times into mathematical equations. Various equations have been proposed : that of BRODY (1945) ; $w = a\,(1 - be^{-kt})$; the logistic equation $w = \frac{a}{1 + be}kt$; and the GOMPERTZ equation $w = ae^{-be^{-kt}}$.

In all these cases, w is the live weight at time t and a, b and k are constants. LAIRD et al. (1965) discussed these equations and showed that of GOMPERTZ was preferable if one wished to describe the growth over a large weight interval.

However, only a short period may be under consideration (5 to 6 months) with an almost linear increase in weight. This is true for the period of fattening bulls from 9 to 15 or 16 months. In this case it is not possible to use the results in the GOMPERTZ equation. In addition, the calculation (by iteration) for a large number of animals is very costly.

Thus it appears simpler to describe the changes of weight with time by equations of the following type :

$$P = a_1 + b_1 t$$

$$P = a_2 + b_2 t + c_2 t^2$$

$$P = a_3 + b_3 t + c_3 t^2 + d_3 t^3$$

An F test between the correlation coefficients enables us to choose of the curve with the best fit. A number of measurements of weight thus make possible calculation of live weight at any time, and most importantly, on the day of slaughtering. This final weight can be related to the measurements made after slaughter (see GEAY, 1975). In this case, the animal must not be under too great a stress before slaughter for its empty live weight could be altered.

C O N C L U S I O N

In conclusion, the purpose of this study has been to emphasize the importance of variation of the gut content on live weight measurement and to make recommendations for its use. Thus it appears necessary to choose the date of weighing in relation to dietary changes and not to compare or measure weights independently of type of diet.

In order to standardize the methods of measurement it is necessary now to decide whether the animals should be fasted or not before weighing them. In the first case fasting must be controlled, in the second case animals should be weighed just after the meal.

Finally, in the course of this study we have tried to relate live weight and time mathematically. Different equations have been proposed which should be discussed if the aim is to describe growth or to assess the live weight at any time during the period considered.

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LIVE ANIMAL MEASUREMENTS AS A MEANS OF EVALUATING ANIMALS IN BEEF PRODUCTION EXPERIMENTS

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Abstract

Appraisal of the use of live animal measurements as a means of evaluating animals in beef production experiments can be based on five pertinent questions: (a) what are we trying to achieve when we measure beef animals?; (b) how accurately can animals be measured?; (c) on the evidence so far obtained, how well do measurements of this kind fulfill the aims of the experiments?; (d) can their value be improved by utilizing the measurements in a certain specified way?; (e) are alternative means of doing the same job available?

Each of these questions is discussed, and the conclusions reached are, (a) any attempt to relate measurements to compositional characteristics requires an estimate of animal shape; (b) the limitations set by the inaccuracy of the method are, for the most part, small enough to allow discrimination even between members of relatively homogeneous groups of animals; (c) the majority of the published data suggests that relationships with gross tissue composition are poor, but correlations with weights of joints may be better; (d) making measurements relative to some basic estimate of size and eliminating the effect of basic size differences on tissue variation by reducing all the variables considered to dimensional parity is suggested; (e) other photographic means of recording shape are considered and special attention is drawn to a moiré method which allows a great diversity of measurements to be made with great accuracy.

Introduction

It has been suggested that participants in this seminar should attempt to fulfil several objectives within each topic covered by the general subject of assessment of carcass and meat characteristics in beef production experiments. It is hoped that the objective concerning the standardisation of practice and recommendations for the future will be met in the discussion that follows this paper. Here attention is focussed more particularly on the validity of pursuing the topic of live measurements in the first instance; only when decisions regarding their usefulness have been made does it seem sensible to discuss uniformity of methods.

Five important questions that raise fundamental points concerning the use of live animal measurements as a means of evaluating animals in beef production experiments are:-

(a) what are we trying to achieve when we measure beef animals?

(b) How accurately can animals be measured?

(c) Based on results obtained so far, how well do measurements predict composition?

(d) Should we use the measurements in a certain specified way which makes allowances for simple variation in overall animal size?

(e) Are alternative means of measuring shape available?

In attempting to answer these questions, greater attention will be focussed on some than on others and this need not reflect the amount of information already known about any particular aspect. Rather it is hoped that those points of most relevance in the context of this seminar receive most attention.

(a) What are we trying to achieve when we measure beef animals?

It is possible to establish certain relationships between external body measurements and some particular structural variable on a simple cause and effect basis. For example, difficulties encountered in calving were investigated by correlating the width of the pelvic opening with external measurements of the pelvic girdle, (Bellows et al., 1971). In a similar way it would seem feasible to obtain an estimate of total bone content of an animal by measuring various skeletal dimensions where little interference from lean or fat deposition exists: fleshing (amount of fat + lean) may be estimated from those measurements of the body which are little affected by skeletal variation, as in certain circumferences. But how can an estimate of fat or lean alone be made? Almost invariably both of these tissues can affect the magnitude of a measurement which may be thought to indicate the degree of deposition of soft tissue. The problem is that the effect of variation of each tissue independently on body dimensions is not understood nearly well enough. However, common experience and some published data, (e.g. Everitt, 1966; Fisher, 1975) shows that variation in the deposition of soft tissues produces gross shape differences. In a rather elementary way, shape can be regarded as being the integrated result of defining the size of a measurement relative to the sizes of the other measurements, for each measurement considered. When attempting to determine the composition of the animal body in terms of individual soft tissues, it is, therefore, a measure of shape which is required. The basic question to be answered, and the one underlying the entire feasibility of this topic, concerns the success with which body measurements quantify shape.

The importance of body measurements in beef production work is not confined to evaluating body composition. Thus Jeffrey and Berg (1972) related size in cows to the ultimate size and condition of their calves, whilst Brown and Schrode (1971) incorporated body measurements into prediction equations on post-measurement growth in calves. Nevertheless, it is the evaluation of body composition which remains as the most important consideration.

(b) <u>How accurately can beef cattle be measured</u>?

One important aspect concerning the use of body measurements in evaluation work is the accuracy with which they can be taken. It is not uncommon to find a statement in the literature which suggests that measurements of the live animal cannot be made with accuracy sufficient to justify their taking (e.g. Hancock, 1954). However, detailed investigations of the accuracy in measuring cows (Lush and Copeland, 1930; Touchberry and Lush, 1950), calves (Taylor, 1963) and steers (Fisher, 1975), suggest that for many measurements the accuracy concerned is enough to discriminate between members of even relatively homogeneous groups of animals. Figure 1 shows the measurements taken on animals at the Meat Research Institute.

Measurements on live cattle may be classified according to the anatomical structure defining them. Such a system would include three categories, namely measurements that are (a) direct estimates of skeletal size, (b) indicative of fleshing with the effect of bone size being non-existent or negligible, and (c) estimates of the combined total produced by both flesh and bone variation. The type of measurement will usually indicate the degree of accuracy with which it may be measured. Thus in Table 1, based on duplicate measurements by the same

TABLE 1

Class of measurement and associated accuracy

Measurement class	Measurement description	Mean (mm)	RSD (mm)
(a) Skeletal estimate only	circumference of cannon (T)	210.5	2.06
	tuber coxae to tuber ischii (C)	469.2	5.60
	sacrococcygeal joint to patella (C)	531.1	6.53
(b) Fleshing estimate only	circumference of hind leg (T)	505.6	18.55
	patella to posterior midline (T)	503.5	19.86

TABLE 1 (Continued)

	Measurement description	Mean (mm)	RSD (mm)
(c) bone + flesh estimate	heart girth (T)	1799.5	15.24
	width shoulders (C)	494.7	12.96
	sacrococcygeal joint to patella (T)	631.5	10.36

T = Tape, C = Calipers

Based on duplicate measurements by one operator on 15 Hereford steers

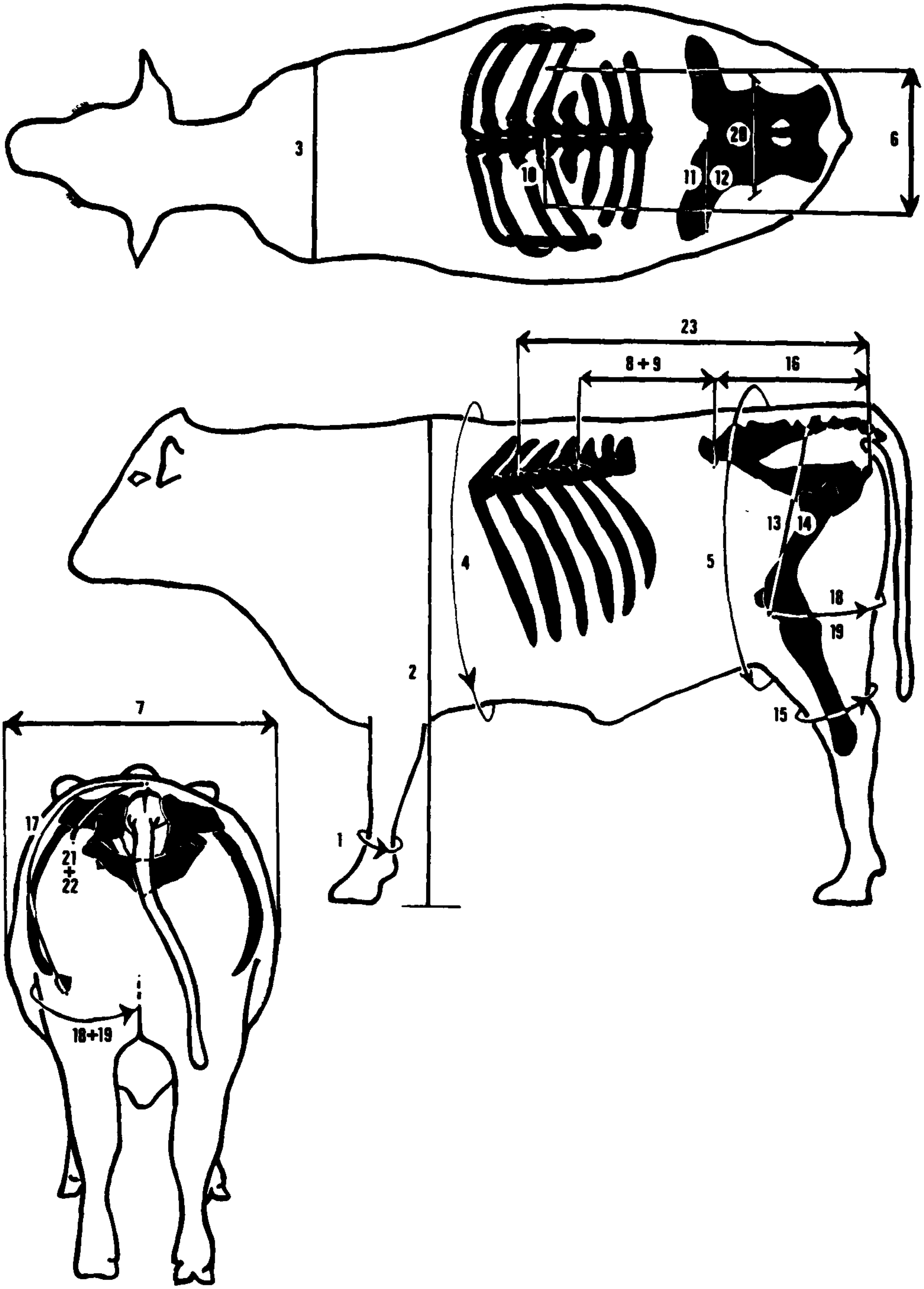
operator on 15 Hereford steers, it can be seen that estimates of skeletal size alone have the highest repeatabilities, as indicated by their residual standard deviations. These are followed by estimates of bone plus flesh where the skeletal structures involved help to stabilise the part of the anatomy involved (as in width of shoulders) or they provide more readily identifiable end reference points for the measurement (as in depth from sacrococcygeal joint to patella). Estimates of the soft tissue only are the least accurate, lacking the advantages provided by the skeletal structures outlined above.

Other factors may be important in determining the accuracy involved in taking any particular measurement and these can be large enough to modify greatly the kind of error suggested on the simple basis of anatomical structure already outlined. Thus distortion in the animals posture, often dependent on the number of skeletal articulations between the two end-points of a measurement and the degree of movement at each joint, can result in purely skeletal measurements having residual standard deviations as high as some measures of fleshing alone. In particular, of those illustrated in Figure 1, length of loin and length of hindquarter are prone to error.

(c) <u>How well do body measurements predict body composition?</u>

Perhaps the enthusiam with which research workers pursued the development of

Fig.1 Measurements on Live Cattle at the M.R.I.



KEY TO FIGURE 1

1. Circumference of Cannon (Tape)
2. Height at Withers (Measuring stick)
3. Width of Shoulders (Calipers)
4. Heart Girth (Tape)
5. Rear Flank girth (Tape)
6. Width of Ribs (Calipers)
7. Width of Paunch (Calipers)
8. Length of Loin (Calipers)
9. Length of Loin (Tape)
10. Depth of Rib Point (Tape)
11. Depth of Hooks (Calipers)
12. Depth of Hooks (Tape)
13. Depth Patella from Tail (Calipers)
14. Depth Patella from Tail (Tape)
15. Circumference of Hind leg (Tape)
16. Length of Pelvic Girdle (Calipers)
17. Depth of Patella from Dorsal Mid-line (Tape)
18. Length from Patella to Posterior Mid-line (Calipers)
19. Length from Patella to Posterior Mid-line (Tape)
20. Width of Rump (Calipers)
21. Depth of Rump (Calipers)
22. Depth of Rump (Tape)
23. Length of Hindquarter (Tape)

methods of estimating composition based on live measurements may be explained, in part, by the results obtained from groups of animals with very variable characteristics and interpreting the results solely in terms of correlation coefficients. High correlations were obtained because the samples were so heterogeneous and in most cases a measure of live weight would have given even higher correlations. Even so, the study of a heterogeneous sample does have its merits, for then the relative differences in dimensions are most pronounced and are noticed. Thus in a study of the changes in body measurements of steers during intensive fattening (Lush 1928), it was discovered that increases in width during this period were relatively greater than increases in any other general direction. Although fatness in this study was not measured directly, but only estimated, this was an important study because it indicated the type of measurement which should give an estimate of the quantity of one of the soft tissue components.

Once the important effect of a large range in weight or size was appreciated, the results obtained from linear measurements and examined in this new light were generally disappointing. Thus, in a review of studies of this kind so far attempted, Orme (1963) concludes that "..... regarding the use of linear live animal measurements to estimate composition in lamb and beef carcasses .... the relationships among these measurements have not been sufficiently high for predictive purposes." This statement covered both prediction of tissue components and weights of joints. In predicting edible portion (closely trimmed, practically boneless retail cuts and lean trim), Busch et al., (1969) concluded that body measurements were of little value, as slaughter weight and all measurements controlled from only 2 to 4% more variation in edible portion than slaughter weight alone. However, working with large numbers of steers falling within very narrow weight ranges (22.7 kg) and using 185 basic measurements with, additionally, ratios of some measurements, Green and co-workers (e.g. Green et al., 1971) found that live measurements were better predictors of wholesale joint weights than slaughter-weight, and indeed, addition of slaughter weight into the list of independent variables did not improve the prediction. The number and system of measurement used here is by far the most exhaustive encountered, and this suggests that measurements of this kind may be of practical value when they are as detailed as this.

(d) Can the value of live animal measurements be improved by using them in a specified way which makes them relative to overall size of the animal?

In this section the question of relative size will be discussed in conjunction with the need to transform all variables in a prediction equation to dimensional parity.

If the dimensions of animal bodies and the volumes of their tissues varied only according to the laws of simple allometry, i.e. being of constant shape and ranging only in size, then any dimension or tissue volume could be predicted from a knowledge of any other dimension or tissue volume, providing the basic geometry of the beef animal was known. But, in addition to this range in size there exists, of course, a range in shape and a range in tissue proportions. It is possible to remove some of the effect of the allometric variation from the total variation by accounting in some way for basic size differences. This may be accomplished by making all measurements relative to some standard skeletal dimension which is assumed to be a constant proportion of total skeletal size. Length of body is an easily obtained reference measurement in carcasses, but an accurate, reliable length measurement of the live animal is most difficult to achieve, and height at withers, or at sacrum, is probably better in this case. Thus in predicting any absolute weight of tissue from one or more body measurements, a measure of basic body size must be included as an independent variable.

The assumption that variation in size can be accounted for by measuring one part of the skeletal framework is a rather crude one. Work by Brown et al., (1973) has shown that bulls of two contrasting body shapes (tall, narrow bodied vs. short and wide) maintain this difference over an age range from 4 to 12 months, and this contrast in shape, especially at 4 months, is likely to be due to different skeletal shapes.

In addition to adjusting the relative sizes, dimensional parity should be maintained for all variables where there is a sufficient range in variable size to justify doing so. Thus in an experiment relating measurements to composition throughout growth all linear measurements should be cubed to relate directly to tissue volumes, (or in practice, tissue mass), as this is already in the cubic dimension. Reducing to dimensional parity and introducing a measure of relative size will account for some part of the existing variation, the exact amount depending on the sample structure.

(e) Are alternative means of measuring animal shape available?

Based on the observations by Lush (1928) that increases in width accompanied increases in fattening, a method was evolved which effectively gave an integrated measure of width over the entire length of beef carcasses, (Fisher, 1975). This was achieved by measuring, from photographic negatives, the profile areas of the carcasses viewed from the dorsal aspect, and adjusting for length differences in the way described in section (d) of this paper. Also, dimensional parity was achieved with tissue volumes, profile areas and carcass lengths. The results were promising in that total fatness was estimated about as accurately as could be achieved by a panel of six experienced judges assessing the carcasses visually. This same technique of obtaining integrated values of width, depth, or any other dimension may be applied to the live animal.

More detailed shape measurements can be made using the stereophotogrammetry method, which involves very expensive equipment, or through other photographic means of which a moiré method is particularly promising, being both cheap to use and accurate. This technique was first applied to carcasses (Speight et al., 1974), and has since been used, with a modified methodology, to record live animal shape successfully (Miles and Speight, 1975). Essentially the moiré method involves the casting of the shadow of a plane, equispaced line grating on to the object by means of a point light source. When viewed through the grating from a point in the plane through the light source parallel to the grating, the moiré pattern is a system of contour lines of equal depth from the grating, produced by the interaction of the two line systems, (shadow and grating). The modifications made for live animal work dispense with the grating which is in danger of being broken as it is placed near the animal. Instead a slide bearing a grid pattern is projected, at a predetermined angle, on to a flat white screen. This "enlarged" grating is photographed and a positive transparency made. The animal is also photographed under the projected grating and when the transparency is superimposed on a print of the animal contours are produced as in the previous method. By moving the transparency grating in a lateral direction with respect to the print, contours can be formed at any plane on the animal and thus made to coincide with any anatomical point whose coordinates may then be determined.

The moiré method offers enormous advantages over conventional linear measurements made on the live animal in terms of accuracy and the variables which can be measured. These include volumes and areas of any desired portions. The stance of the animal must be standardised here also to avoid introducing anatomical distortion, but it is much easier to do this for one photographic shot than for dozens of measurements.

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ULTRASONIC MEASUREMENTS OF LIVE CATTLE

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Abstract

The importance of ultrasonic measurement in cattle experiments, cattle breeding and cattle production is discussed. It is shown that ultrasonic measurements of m.long. dorsi on the live animal yield approximately the same amount of information on the carcass composition as the muscle area measured from a cross-sectional picture on the carcass.

Different ultrasonic equipment is described, and a review of the latest experimental results with Krautkrämer, Scanogram and SVC equipment is given.

Introduction

Thoughout the history of cattle production the development of methods of indirect measurements of body composition of live cattle has received a great deal of attention. The main reasons for this are a need for:

1. A selection programme for breeding bulls of beef and dual purpose cattle breeds based on their performance (breeding value) in terms of carcass quality.
2. A means of identifying animals at a specified degree of fatness in commercial beef production (and in various cattle experiments).

So far the selection of cattle for slaughtering or breeding purposes has mainly been based on a subjective evaluation of conformation, fleshiness and fatness of the live animals. However, there seems to be a great need for the development of more objective methods to replace/supplement the existing subjective methods. Results of objective measurements are easier to compare from experiment to experiment, from country to country and from time period to time period. Objective measurements have in general a higher repeatability between and within technicians and in general higher coefficients of heritabilities than subjective measurements.

Numerous objective methods of indirect description of the anatomical body composition in live animals have been developed and among these the ultrasonic technique appears to have a considerable potential as a non-destructive and relatively accurate method.

The ultrasonic measurements of live cattle are mainly concentrated upon the musculature and subcutaneous fat layer in the loin and back. In this region the musculature consists mainly of m. long. dorsi. It is a regular and well defined muscle relatively easy to measure. And in these regions the skeletal features are easy to locate, in order that the position of measurements can be reproduced for each animal.

Relationships between m. long. dorsi area, subcutaneous fat layer and body composition

The area of m. long. dorsi and the subcutaneous fat layer have been studied for many years as indicators of carcass composition. There has been a great variation among the obtained results. In experiments with a constant carcass weight the phenotypical correlations between muscle area and content of lean have ranged from 0.4 to 0.7, and between subcutaneous fat layer and content of lean from -0.6 to -0.8. In experiments with a greater variation in carcass weight the muscle area has not been that good as an indicator of carcass composition. The main reason for this seems to be that increasing weight is associated with a greater muscle area, but also a lower percentage of lean (increasing fatness). This effect of fatness is enough to obscure the positive relationship between muscle area and relative lean content.

Comparisons of subjective and objective measurements

In table 1 are shown results from a Danish experiment with subjective and objective measurements of body composition. The data derives from 89 RDM (Red Danish Cattle) and 66 SDM (Black and White Danish Cattle) young bulls slaughtered at an age of 450 kg. After slaughter the right side of each animal was dissected (jointing and tissue separation by the Meat Research Institute in Roskilde). The visual assessment of fleshiness is made on a 1-10 scale. As discussed earlier in this paper the m. long. dorsi area measured on the carcass gives a relatively good description of the carcass composition. Ultrasonic measurements of the same muscle on the live animal give approximately the same amount of information as the measurements on the carcass (see also table 2 and table 3). Visual assessments on live animals can, made by a person with a great deal of experience, give

Table 1. Phenotypical correlations between subjective and objective measurements and carcass composition. (450 kg's young bulls with av. % fat = 15.2 and CV = 11.2).

	RDM (n = 89)		SDM (n = 66)	
	% pistol-lean	lean/bone	% pistol-lean	lean/bone
Muscle area (photo - carcass)	0.56	0.52	0.54	0.51
Muscle area (ultrasonic - live anim.)	0.35	0.31	0.41	0.50
Fleshiness score (back - live anim.)	0.32	0.51	0.26	0.55
Fleshiness score (loin - live anim.)	0.22	0.36	0.06	0.42
Fleshiness score (thigh - live anim.)	0.31	0.40	0.17	0.40

Table 2. Results from SVC ultrasonic measurements. (450 kg dual purpose young bulls with av. % fat = 14.9, CV = 12.4 and n = 295).

	% pistollean		lean/bone	
	r_p	RSD	r_p	RSD
Muscle area (photo - carcass)	0.49	0.8	0.45	0.21
Muscle area (ultrasonic - live anim.)	0.37	0.9	0.40	0.21
Muscle area/Fat area (ultrasonic live anim.)	0.55	0.8	0.32	0.23

	Average	SD	h^2
Muscle area (photo - carcass)	61.3	5.7	0.69 ± 0.23
Muscle area (ultrasonic - live anim.)	54.3	7.1	0.49 ± 0.21
Muscle area/fat area (ultrasonic - live anim.)	3.98	0.52	0.46 ± 0.21

much information on the lean/bone ratio in the carcass, whereas the prediction of percentage pistollean is less satisfactory. This is partly due to the influence of variation in fatness on the relative amount of pistollean.

The results in table 2 are based on a large number of young bulls, and the ultrasonic measurements made with technically more advanced equipment. These results show a great genetic variation in the muscle area (both measured from a photograph of the cut carcass and from an ultrasonic picture of the live animal). The results also confirm that ultrasonic measurements contain approximately the same amount of information on the body composition as muscle area measurements from cross-sectional pictures on the carcass. Furthermore table 2 shows that even with relatively lean young bulls of dual purpose breeds it is possible to improve the description of the percentage of pistollean by including the subcutaneous fat layer in the ultrasonic measurements. But this is much more pronounced in a Danish experiment with ultrasonic measurements of crossbred young bulls (table 3), where the coefficient of variation in percentage of fat is 20.

In this experiment the phenotypical correlation between the ultrasonic measurements and percentage of pistollean increases from approximately 0.40 to 0.80 by the inclusion of measurements of the fat layer.

Table 3. Results from SVC ultrasonic measurements. (450 kg crossbreed young bulls with av. % fat = 16.4, CV = 20.1 and n = 29).

	% pistollean		lean/bone	
	r_p	RSD	r_p	RSD
Muscle area (ultrasonic - live anim.)	0.42	1.8	0.47	0.29
Muscle area/Fat area (ultrasonic live anim.)	0.78	1.0	0.59	0.24
Muscle area/Fat area (photo - carcass)	0.75	1.0	0.39	0.31

Description and comparisons of ultrasonic equipment

The first work on ultrasonic measurements on cattle was described by Temple et al. (1956) and Stouffer et al. (1959). Among others, Meyer et al. (1966) show a high correlation between carcass muscle area, carcass fat thickness and ultrasonic measurements prior to slaughter. But in papers by Wedekind (1964) and La Chevallerie (1968) it was concluded that no significant relationship existed between scanning results and carcass composition estimated by dissection. Since then, however, the ultrasonic technique has been improved considerably, and in the last few years important results in this field have been published (Andersen, 1975).

Presently three types of equipment are being used for ultrasonic measurements of cattle: The "Krautkrämer" equipment from Germany is based on the A-technique and the "SVC Scanner" from Denmark on a complex-B-scanning principle. The "Scanogram" equipment from the USA is based on a modified A-technique, and it is also a continuous scanning instrument.

The "Krautkrämer", utilizing the A-technique, is a simple construction and relatively cheap to buy and cheap to use. Gillis et al. (1973) compared the "Krautkrämer" and U.S. "Scanogram" equipment and concluded that the two techniques were of the same value for the measurement of fat thickness. Estimates of the muscle area were a little more accurate using the "Krautkrämer". The correlations between carcass and ultrasonic muscle area ranged in different series from 0.32 to 0.88 with the "Krautkrämer" and from 0.17 to 0.56 with the "Scanogram". The corresponding residual standard deviations (RSD) ranged from 2.3 to 5.3 cm^2 and from 5.2 to 6.1 cm^2 respectively. But according to Gillis et al. the "Krautkrämer" was a very time consuming piece of equipment and required an experienced operator.

The U.S. "Scanogram" is also relatively cheap and robust equipment. Tulloh et al. (1973) used equipment of this type in an experiment with 14 Aberdeen Angus and 15 Holstein Friesian steers. The correlations between ultrasonic and carcass fat depth ranged from 0.56 to 0.94 and the RSD from 2.8 to 5.4 mm. For muscle area measured with the "Scanogram" and directly on the carcass the corresponding figures ranged from 0.32 to 0.76 and from 4.1 to 6.8 cm^2. The correlation between ultrasonic fat thickness and percentage of dissected muscles ranged from -0.60 to -0.77 and the corresponding RSD from 3.3 to 2.1 %. The correlations between the eye muscle area measured ultra-sonically and the percentage of dissected muscle were low and negative and ranged from -0.12 to -0.36.

The Danish "SVC" equipment is more complicated in use and service and more expensive to buy. It is especially useful at performance test stations and research stations (Andersen, 1970). Results obtained with this equipment are presented in table 1, table 2 and table 3.

A new piece of Danish equipment, the "DANSCAN", which is of simplified construction, has been developed and was first used in the autumn 1975.

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NOTE ON THE USE OF THE SCANOGRAM ON LIVE CATTLE TO PREDICT CARCASS COMPOSITION

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Abstract

The results of two trials involving the Scanogram are described. In one, various subcutaneous fat thickness and area measurements obtained by Scanogram were compared as predictors of tissue percentages in the carcass. The best single predictor of percentage lean in the side was a measurement of fat area at the 10th rib. Combining measurements improved precision. At most positions a 2 to 1 scan was superior to a 1 to 1 scan.

In the second trial, the Scanogram was used to select cattle for slaughter at a similar level of fatness in a test of the efficiency of different beef breeds. Out of 345 cattle, 89% were slaughtered at the desired level of fatness.

Note on the use of the Scanogram on live cattle to predict carcass composition

A. A trial was carried out to compare different subcutaneous fat thickness and area measurements, taken from photographs of ultrasonic scans of live cattle obtained by using the Scanogram, as predictors of tissue percentages in the carcass. Transverse scans were taken at the 6th, 10th and 13th ribs and at the position of the 3rd lumbar vertebra in the week prior to slaughter on 31 steers comprising 11 Simmental x Friesian, 5 Friesian, 7 Limousin x Friesian and 8 Hereford x Friesian. Two sizes of scan were taken: 2 to 1 (half life-size in both depth and width) and 1 to 1 (life-size in depth and half life-size in width)." Two to one scans were not taken at the 6th rib. The following subcutaneous fat thicknesses and areas were taken from each Scanogram photograph.

(1) Thickness over the L. dorsi at 5 cm from the dorsal mid-line.
(2) Thickness over the L. dorsi at 7½ cm from the dorsal mid-line.
(3) Thickness over the L. dorsi at 10 cm from the dorsal mid-line.
(4) Thickness over the L. dorsi at 12½ cm from the dorsal mid-line.
(5) Area from the dorsal mid-line to a position 15 cm from it.
(6) Area over the L. dorsi.

The left side of each carcass was dissected using the procedure described by Cuthbertson, Harrington and Smith (1972).

The important results are set out in Table 1. The best single predictor of percentage lean in the side was the 0-15 cm fat area taken at the 10th rib using a 2 to 1 scan. The best fat thickness measurement was that taken 10 cm from the mid-line at the position of the 3rd lumbar vertebra using a 2 to 1 scan. The best pair of measurements in multiple regression was the fat area, 0 to 15 cm from the mid-line (2 to 1 scan) plus the same area at the 13th rib (1 to 1 scan). At most positions the 2 to 1 scan was superior to the 1 to 1 scan.

B. The Scanogram is being used in the MLC Beef Breed Evaluation Programme to select cattle for slaughter at a similar level of fatness. The programme is being conducted at two centres - Edinburgh and Nottingham. The unit at Edinburgh is concerned with beef production from the suckler herd, and the main beef breeds are being compared when crossed with Hereford x Friesian and Blue-Grey females. The unit at Nottingham is concerned with beef production from the dairy herd, and beef breeds are being compared when crossed with Friesian females.

Cattle are slaughtered when, on the basis of the fat areas measured by Scanogram at 0-15 cm from the mid-line at the 10th and 13th ribs, they are judged to have a subcutaneous fat percentage corresponding with a given fat class in the MLC Beef Carcase Classification Scheme. At Edinburgh, it is the aim to slaughter cattle at fat class 3 (7.5 to 10.4% subcutaneous fat in the carcass), while at Nottingham fat class 2 is used (4.5 to 7.4% subcutaneous fat). In practice, some 15% of cattle were slaughtered at lower or higher fat classes because they were from breeds which are too late or too early maturing respectively for the production system used. For details of the classification scheme, see MLC Marketing and Meat Trade Technical Bulletin, No. 22. Carcasses are evaluated using a standardised commercial fat trimming and deboning procedure.

Results are available for a total of 345 cattle. Of these, 306 (89%) were placed in the correct fat class using the Scanogram, 38 (11%) were one fat class out and one animal was two fat classes out. Since the majority of carcasses at a particular evaluation unit were in the same fat class, there was little variation in percentage fat trim (SD = 2.04) and the data were not well suited to testing the relationship between Scanogram

TABLE 1

Means and standard deviations for live weight at evaluation, side weight and lean and subcutaneous fat as percentages of side weight (ex KKCF)

	Mean	SD
Live weight (kg)	433.3	52.20
Side weight (kg)	112.3	15.06
% lean	61.2	3.19
% subcutaneous fat	7.7	1.69

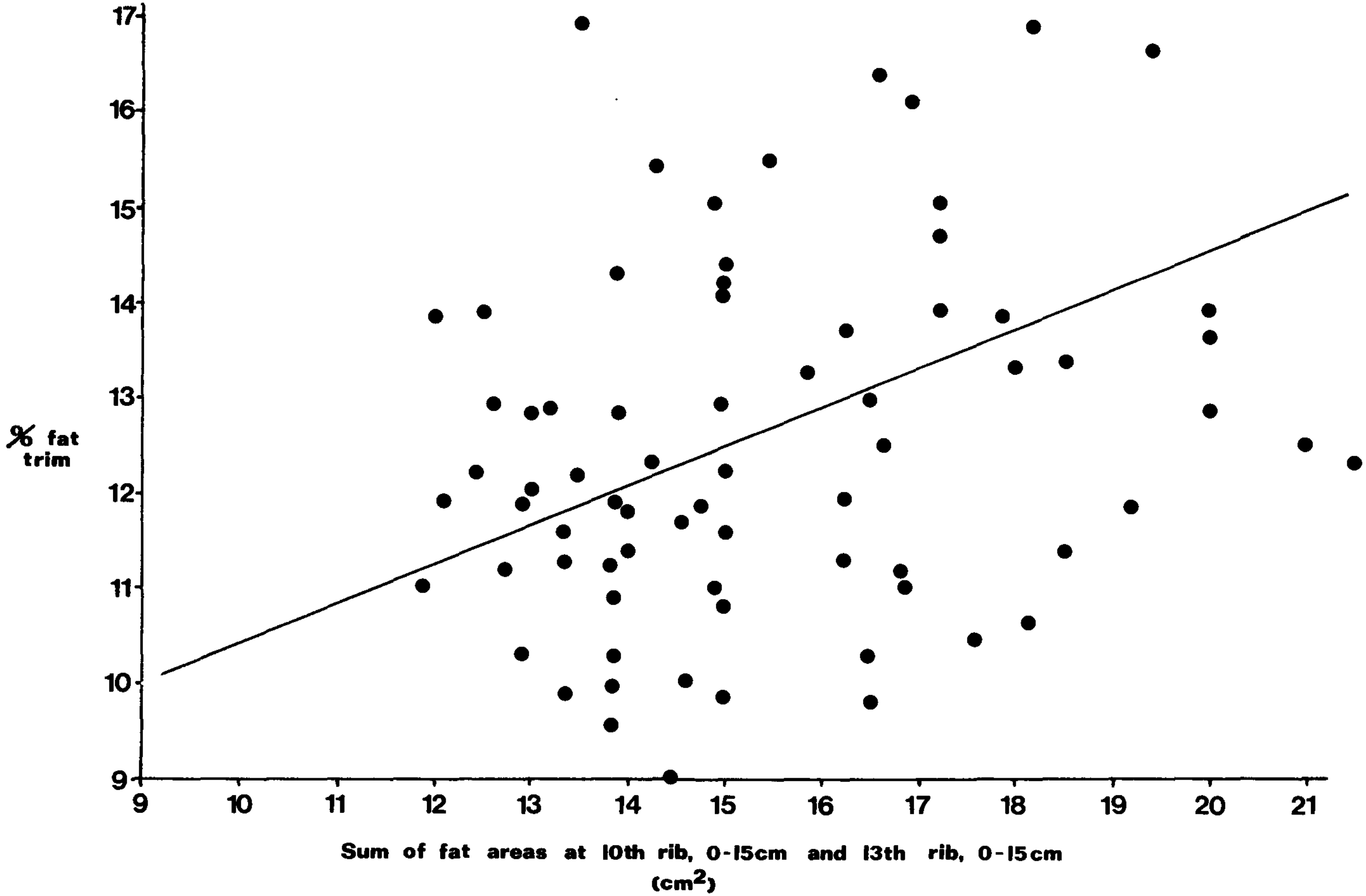
Residual standard deviations for the prediction of percentage lean and subcutaneous fat in the side from subcutaneous fat thickness and area measurements

	% lean	% subcutaneous fat
Best single predictors:		
10th rib : fat area 0-15 cm† : 2-1 ‡	2.02	1.12
13th rib : fat area 0-15 cm : 1-1	2.29	1.05
Best fat thickness measurements:		
3rd lumbar vert. : 10 cm : 2-1	2.29	1.31
10th rib : 5 cm : 2-1	2.51	1.31
13th rib : 7½ cm : 2-1	2.51	1.37
Best pairs of measurements in multiple regression		
{ 10th rib : fat area : 0-15 cm : 2-1 13th rib : fat area : 0-15 cm : 1-1	1.89	0.95
{ 10th rib : fat area : 0-15 cm : 2-1 3rd lumbar vert. : fat depth : 10 cm : 2-1	1.84	1.07
{ 10th rib : fat area : 0-15 cm : 2-1 13th rib : fat area : 0-15 cm : 2-1	1.98	0.98

† Distance from the dorsal mid-line

‡ Size of scan

PERCENTAGE FAT TRIM AGAINST SCANOGRAM FAT AREA



fat areas and fat trim. The correlation pooled within evaluation unit between fat trim as a percentage of carcass weight and Scanogram fat area was 0.41 (RSD for percentage fat trim = 1.86). The attached graph shows the relationship between these two characters for cattle from the Nottingham unit.

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THE USE OF AN ULTRASONIC TECHNIQUE 'IN VIVO' FOR BEEF CARCASS EVALUATION*

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Abstract

Experiments were carried out on 72 beef cattle (Table 1) in order to verify the use of an ultrasonic technique 'in vivo' with live (X_1) and gross live (X_2) weight to estimate some carcass characteristics.

LD (longissimus dorsi) area (X_3), scanned between the 12th and 13th rib prior to slaughtering, was highly related to the actual tracing area (r=0.88 to 0.99; $P < 0.001$) on the carcass. However, its value in estimating either the total weight of wholesale cuts or their quality was less than that of using X_1 and X_2. Some partial ($r_{Y_iX_3.X_2}$) and multiple (r_{Y_iZ} and $r_{Y_iX_2X_3}$) correlations within crossbreed or breed did not improve estimates obtained by simple correlations ($r_{Y_iX_1}$ and $r_{Y_iX_2}$).

Introduction

The ultrasonic technique 'in vivo' for the evaluation of various characteristics of a number of species of meat animals is now routinely used in farm observations in several technically advanced countries. From the 'somascope' of Temple et al. (1956) who partly followed the human technique (Wild, 1950; Howry and Bliss, 1952), more technically advanced instruments were developed for practical purposes.

The experiment described in this paper was designed to estimate the phenotypic relationships between live beef cattle and carcass measurements, with the greatest importance on an ultrasonic technique. From these relationships indications are derived in order not only to obtain a more satisfactory programme which is used in selection, but also their usefulness in verifying the effectiveness of the instrument in its designed rôle.

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Table 1. Values of some parameters.

Breed or Crossbreed	N	Variable: weight, kg: live $\bar{x} \pm \sigma$	CV %	gross live $\bar{x} \pm \sigma$	CV %	'in vivo' loin eye area, cm^2 $\bar{x} \pm \sigma$	CV %
Italian Friesian (IF)	16	489.0 ± 12.7	3	466.0 ± 10.4	2	78.8 ± 9.6	12
Poland Friesian (PF)	22	428.0 ± 19.6	5	408.0 ± 19.8	5	80.0 ± 7.8	10
Red Pied Bavarian (RPB)	16	509.0 ± 15.4	3	483.0 ± 17.1	4	97.5 ± 7.9	8
Charolais x Italian Friesian (CxIF)	18	568.0 ± 21.7	4	544.0 ± 19.4	4	102.3 ± 10.8	11

According to Wilton et al. (1973), the practical use of the ultrasonic technique is based upon the efficiency to estimate the qualitative rather than the quantitative evaluation of a carcass. In order to achieve a genetic improvement, the carcass value is strictly related to the value of the cuts. On the other hand an estimate of the breeding value of an animal cannot be obtained from carcass observations because of the slaughtering of the potential sire unless a great deal of frozen semen has been made available. An indirect estimate can be carried out either through several carcass observations of animals closely related to the potential sire or with the live evaluation of the sire, obtained from observations made after the slaughtering. Evidently the two methods can be employed at the same time and it is possible to combine these results to improve the estimate. It could be useful to leave out carcass observations of related animals and to carry out only live measurements. The unit price of the genetic improvement and the breeding structures decide the method to be used.

Material and Methods

72 beef cattle were used in this study (Table 1). The variables studied are described in Table 2. Type of housing, feeding, methods of ultrasonic measurements, slaughtering, aging and carcass cutting were appropriately standardized. Ultrasonic estimates of LD were made between the 12th and 13th rib with a Scanogram Model 722 (Ithaco, USA). The actual tracing of the loin eye was obtained

Table 2. Considered variables.

Variable		Variable		
X_1 ,	Weight (kg), live	Y_{16} ,	Percent	Y_7
X_2 ,	Weight (kg), gross live$^{(A)}$	Y_{17} ,	Percent	Y_8
X_3 ,	Loin eye area "in vivo", cm^2	Y_{18} ,	Percent	Y_9
Y_1 ,	Loin eye area actual tracing, cm^2	Y_{19} ,	Percent	Y_{10}
Y_2 ,	Weight (kg), net live (B)	Y_{20} ,	Percent	Y_{11}
Y_3 ,	Weight (kg), after cooling side	Y_{21} ,	Percent	Y_{12}
Y_4 ,	Weight (kg), after cooling fore quarter	Y_{22} ,	Percent	Y_{13}
Y_5 ,	Weight (kg), after cooling hind quarter	Y_{23} ,	Percent	Y_{14}
Y_6 ,	Weight (kg), total trimmed cuts	Y_{24} ,	Percent	Y_{15}
Y_7 ,	Weight (kg), 1st quality A$^{(C)}$			
Y_8 ,	Weight (kg), 2nd quality A$^{(C)}$			
Y_9 ,	Weight (kg), 3rd quality A$^{(C)}$			
Y_{10},	Weight (kg), 1st quality M$^{(C)}$			
Y_{11},	Weight (kg), 2nd quality M$^{(C)}$			
Y_{12},	Weight (kg), 3rd quality M$^{(C)}$			
Y_{13},	Weight (kg), 1st quality R$^{(C)}$			
Y_{14},	Weight (kg), 2nd quality R$^{(C)}$			
Y_{15},	Weight (kg), 3rd quality R$^{(C)}$			

(A) Immediately before slaughter after 12 hours fasting

(B) Live weight at slaughter with the weights of the gut contents substracted

(C) Different criteria of classification.

on the carcass after 7 days of aging at 0 - 2°C. The cuts were classified as 1st, 2nd and 3rd quality according to three different methods: A, M and R.

Results and Discussion

Significant simple correlation coefficients between live (X_1) or live gross (X_2) weight and dependent variables (Y_i) would tend to increase in number according

Table 3. Simple and partial correlation coefficients within breed or crossbreed.

Variable	Breed or Crossbreed									
	CxIF				RPB				IF	
	Variable									
	X_1	X_2	X_3	$X_3 \cdot X_2$	X_1	X_2	X_3	$X_3 \cdot X_2$	X_1	X_2
X_1		0.92***	0.46			0.85***	0.06			0.63**
X_2			0.54*				0.01			
Y_1	0.39	0.49	0.88***	-0.84***	0.09	0.03	0.99***	0.99***	0.14	-0.01
Y_2	0.88***	0.96***	0.52*	0.03	0.79***	0.96***	-0.03	0.09	0.68**	0.76***
Y_3	0.59*	0.68**	0.29	0.13	0.82***	0.75***	-0.06	0.09	0.65**	0.67**
Y_4	0.66**	0.74**	0.28	0.21	0.69***	0.63**	-0.11	0.15	0.59*	0.53*
Y_5	0.35	0.43	0.23	0.01	0.79***	0.71***	0.03	0.04	0.63**	0.71**
Y_6	0.01	0.10	-0.01	0.07	0.82***	0.76***	0.15	0.22	0.51*	0.65**
Y_7	0.25	0.34	0.26	0.10	0.70***	0.75***	0.18	0.27	0.54*	0.64**
Y_8	-0.06	0.01	-0.08	0.10	0.66**	0.56**	-0.06	0.08	0.15	0.39
Y_9	-0.38	-0.38	-0.45	0.31	0.45*	0.29	0.27	0.28	0.36	0.31
Y_{10}	0.34	0.44	0.31	0.10	0.73***	0.78***	0.17	0.27	0.49*	0.62**
Y_{11}	-0.64**	-0.60*	-0.45	0.19	0.62**	0.38	0.04	0.05	0.40	0.58*
Y_{12}	0.09	0.08	-0.33	0.45	0.57**	0.50*	0.05	0.06	0.19	0.05
Y_{13}	0.16	0.26	0.22	0.09	0.68***	0.74***	0.22	0.32	0.54*	0.63**
Y_{14}	0.38	0.42	0.22	0.01	0.53*	0.55*	-0.03	0.03	0.43	0.67**
Y_{15}	-0.28	-0.25	-0.31	0.21	0.67**	0.53*	0.07	0.08	0.24	0.33
Y_{16}	0.35	0.35	0.41	0.28	-0.47*	-0.28	0.01	0.01	0.09	-0.02
Y_{17}	-0.10	-0.09	-0.12	0.09	0.34	0.24	-0.22	0.23	-0.31	-0.13
Y_{18}	-0.45	-0.46	-0.52	0.36	0.29	0.13	0.26	0.26	0.26	0.17
Y_{19}	0.67**	0.69**	0.66**	0.47	-0.41	-0.16	0.03	0.03	-0.23	-0.31
Y_{20}	-0.80***	-0.80***	-0.56*	0.25	0.34	0.06	-0.03	0.03	0.28	0.46
Y_{21}	0.10	0.07	-0.36	0.47	0.37	0.33	-0.01	0.01	-0.02	-0.20
Y_{22}	0.21	0.22	0.34	0.27	-0.46*	-0.29	0.07	0.07	0.13	0.02
Y_{23}	0.55*	0.52*	0.33	0.06	-0.40	-0.33	-0.20	0.21	0.01	0.24
Y_{24}	-0.40	-0.40	-0.42	0.26	0.52	0.35	0.01	0.01	-0.12	-0.10

Breed or crossbreed									
IF		PF				CxIF+RPB+IF+PF			
Variable									
X_3	$X_3 \cdot X_2$	X_1	X_2	X_3	$X_3 \cdot X_2$	X_1	X_2	X_3	$X_3 \cdot X_2$
0.11			0.94***	0.29			0.99***	0.66***	
-0.06				0.04				0.64***	
0.99***	0.99***	0.29	0.04	0.99***	0.99***	0.65***	0.64***	0.97***	0.95***
0.20	0.38	0.92***	0.96***	0.12	0.29	0.98***	0.99***	0.66***	0.28*
0.27	0.42	0.69**	0.73***	0.17	0.21	0.96***	0.96***	0.64***	0.10
0.23	0.31	0.70**	0.75***	0.15	0.19	0.95***	0.96***	0.63***	0.08
0.27	0.45	0.64**	0.66**	0.18	0.21	0.95***	0.95***	0.63***	0.10
0.27	0.40	0.55*	0.57*	0.23	0.25	0.93***	0.93***	0.64***	0.17
0.34	0.49*	0.56*	0.60**	0.15	0.16	0.94***	0.94***	0.68***	0.29*
0.03	0.06	0.36	0.30	0.36	0.36	0.83***	0.83***	0.55***	0.05
0.12	0.14	0.44	0.58*	-0.18	0.25	0.66***	0.66***	0.37**	0.09
0.32	0.45	0.56*	0.58*	0.22	0.24	0.94***	0.95***	0.68***	0.31**
0.13	0.21	0.43	0.41	0.25	0.25	0.75***	0.75***	0.44***	0.07
-0.02	0.01	0.30	0.31	0.04	0.03	0.71***	0.70***	0.39***	0.11
0.34	0.49*	0.66**	0.68**	-0.03	0.08	0.93***	0.93***	0.65***	0.21
0.03	0.09	0.54*	0.56*	0.18	0.19	0.90***	0.90***	0.61***	0.10
0.13	0.16	0.61**	0.58*	0.13	0.13	0.79***	0.78***	0.48***	0.05
0.15	0.15	-0.13	-0.07	-0.27	0.27	-0.13	-0.12	-0.05	0.03
-0.19	0.20	0.04	-0.07	0.36	0.36	-0.04	-0.05	-0.07	0.06
0.05	0.06	0.18	0.34	-0.36	0.40	0.24*	0.23*	0.02	0.17
0.02	0.00	-0.08	-0.03	-0.11	0.11	-0.15	-0.13	-0.10	0.02
0.04	0.07	0.07	0.02	0.15	0.15	0.10	0.08	-0.09	0.19
-0.13	0.14	0.01	0.01	-0.09	0.09	0.16	0.15	-0.04	0.18
0.16	0.16	0.37	0.38	-0.26	0.26	-0.12	-0.11	-0.05	0.02
-0.35	0.35	0.26	0.26	0.05	0.04	-0.13	-0.12	-0.11	0.04
-0.03	0.03	0.48*	0.41	0.02	0.01	0.13	0.11	-0.06	0.18

to the size of the breed group. Generally this is true as reported in Table 3, for absolute values (Y_1 - Y_{15}). Correlation coefficients are higher using X_2 rather than X_1. This is true for the crossbreed CxIF and the breeds IF and PF, but not for RPB. Within crossbreed and breed (Table 3), both X_1 and X_2 were highly and significantly correlated: (i) with net live weight Y_2 (r=0.68 to 0.92 and from 0.76 to 0.96 respectively; P<0.001); (ii) with chilled side weight Y_3 (r=0.59 to 0.82 and 0.53 to 0.74 respectively; P<0.05 to 0.001); (iii) with fore quarter weight Y_4 (r=0.60 to 0.70 and 0.53 to 0.74 respectively; P<0.01 - 0.001); (iv) with hind quarter weight Y_5 (r=0.63 to 0.79 and 0.66 to 0.71 respectively; P<0.01 - 0.001) except CxIF; (v) with total cuts weight Y_6 (r=0.51 to 0.82 and 0.57 to 0.76 respectively; P<0.05 - 0.001), excepted CxIF; (vi) with 1st quality cuts weight Y_7, Y_{10} and Y_{13} (r=0.54 to 0.70, 0.60 to 0.75; 0.49 to 0.73, 0.58 to 0.78; 0.54 to 0.68 and 0.63 to 0.64 respectively; P<0.05 - 0.001), excepted CxIF; the 2nd and 3rd quality cuts do not behave in a similar manner to 1st quality cuts because: (a) the different criteria involved in 2nd and 3rd cuts classification; (b) the imprecision of anatomical boundaries of some cuts; (c) the individuality of heterogonic growth of the concerned regions. A proof of these differences can be drawn from the coefficients of variation (CV) which are smaller for 1st cuts (4 - 7 per cent) compared with the 2nd (7 - 14 per cent) and 3rd (11 - 24 per cent) quality cuts. In the crossbreed CxIF the smaller variability of chilling yield, because of the greater uniformity of F_1 hybrids, has produced lower correlation coefficients as reported by Watkins et al. (1967).

The loin eye area evaluated 'in vivo' (X_3) within breed or crossbreed (Table 3), were found to be: (i) not related to X_1, X_2 or Y_2, except X_2 and Y_2 within the crossbreed CxIF (r=0.54 to 0.52 respectively; P<0.05); (ii) highly related to actual tracing area of LD (Y_1) (r=0.88 to 0.99; P<0.001). Many researchers have found significant correlation coefficients ranging from 0.22 to 0.89, but mostly falling around 0.6 or higher (Stouffer et al., 1961; Davis and Long, 1962; Hedrick et al., 1962; Watkins et al., 1967; Gillis et al., 1973; Wilton et al., 1973). This shows the value of the ultrasonic technique to evaluate loin eye area; it must be emphasized that the small differences between the loin eye area measured ultrasonically and the actual tracing area are due to several factors: handling practices, sound frequency variability, positional variation of animals, air trapping, transducer pressure, conformation of scanned region and fat thickness. However, particularly on the last factor, there is no general agreement: Hedrick et al. (1962) reported that, as fat thickness increases, the accuracy of ultrasonic estimates decreases; this result was not consistent with the data reported by Watkins et al. (1967). According to the above mentioned authors, the loin eye area, ultrasonically evaluated 'in vivo', was generally underestimated when compared with the actual tracing on the carcass, except within the breed RPB. This difference may be due to the stress applied to the hanging carcass from the Achille's tendon during aging so that the LD muscle, being compressed at both ends, becomes shorter and more compact and tends to be expanded in the cross-sectional area near the 10-13th rib section, just where the ultrasonic measurements are carried out. For this reason it is very important, at the time of tracing the actual area, to locate exactly the median section between the 12th and the 13th rib, to correspond with the ultrasonic area; (iii) not related to other variables (Y_3 - Y_{24}). With gross live weight X_2, held constant, the correlation coefficients do not change significantly.

The values of simple correlation coefficients $r_{Y_i X_2}$ are quite similar to their respective multiples $r_{Y_i X_2 X_3}$; the difference is greater with multiple correlation coefficients $r_{Y_i Z}$, in all cases the differences $r_{Y_i Z} - r_{Y_i X_2 X_3}$ are not statistically significant, even if $r_{Y_i Z}$ are more useful to estimate the dependent variables Y_{16} - Y_{24} (Table 4).

Combining all groups, the values of $r_{Y_i X_j}$ (i=1-15, j=1-3) and of $r_{X_j X_j}$ show a marked increase over within group, being highly significant (P<0.001; Table 3), because of the greater variability of the studied variables. The simple correlation coefficients $r_{Y_i X_3}$ are greater than the respective partial coefficient $r_{Y_i X_3 . X_2}$, that is with gross live weight constant. Therefore the significance of correlation $r_{Y_i X_3}$ is due to variable X_2. The multiple correlation values $r_{Y_i X_2 X_3}$ are quite similar to the respective $r_{Y_i X_2}$. This shows that the variable X_3 failed significantly to improve the estimates between X_2 and Y_1 - Y_{15}. Comparing the values of $r_{Y_i X_2}$ and $r_{Y_i X_1}$ to $r_{Y_i Z}$ and $r_{Y_i X_2 X_3}$ (Table 3 and 4) the same results are obtained. On the contrary, the values of $r_{Y_i X_2 X_3}$ and $r_{Y_i Z}$ are remarkably greater than that of $r_{Y_i X_1}$ and $r_{Y_i X_2}$ with Y_{16} - Y_{24} variables, even if not statistically significant.

Loin eye area be estimated accurately by the ultrasonic technique 'in vivo' but it is not a good estimator of total cuts weight and of 1st, 2nd and 3rd quality cuts. Significant relationships between loin eye area and weights of several cuts (round, chuck, rib, short loin and loin end; r=0.71 to 0.80) are reported by Davis et al. (1964), and separable lean weight of the same cuts

Table 4. Multiple correlation coefficients within breed or crossbreed.

Variable	Breed or Crossbreed									
	CxIF		RPB		IF		PF		CxIF+RPB+IF+PF	
	variable									
	X_2X_3	$z(^1)$	X_2X_3	$z(^1)$	X_2X_3	$z(^1)$	X_2X_3	$z(^1)$	X_2X_3	$z(^1)$
Y_1	0.88***	0.91**	0.99***	0.99***	0.99***	0.99***	0.99***	0.99***	0.97***	0.97***
Y_2	0.96***	0.97***	0.96***	0.97***	0.80***	0.87**	0.97***	0.97***	0.99***	0.99***
Y_3	0.69*	0.73	0.76***	0.90***	0.74**	0.83*	0.75**	0.89**	0.96***	0.97***
Y_4	0.75**	0.80**	0.64*	0.77*	0.59*	0.69	0.76**	0.89**	0.96***	0.96***
Y_5	0.43	0.63	0.71**	0.84**	0.77**	0.87**	0.68**	0.84*	0.95***	0.95***
Y_6	0.12	0.28	0.78***	0.86**	0.72**	0.79*	0.61*	0.68	0.93***	0.94***
Y_7	0.36	0.48	0.78***	0.81*	0.74**	0.85*	0.61*	0.69	0.95***	0.95***
Y_8	0.10	0.28	0.56*	0.74*	0.40	0.52	0.46	0.54	0.83***	0.85***
Y_9	0.47	0.59	0.39	0.69	0.34	0.56	0.62*	0.77	0.66***	0.68***
Y_{10}	0.45	0.50	0.80***	0.81*	0.71**	0.83*	0.62*	0.69	0.95***	0.96***
Y_{11}	0.62*	0.68	0.38	0.84**	0.61*	0.63	0.47	0.53	0.75***	0.81***
Y_{12}	0.45	0.63	0.50	0.59	0.54	0.50	0.31	0.48	0.70***	0.72***
Y_{13}	0.28	0.47	0.77***	0.80*	0.74**	0.86**	0.68**	0.77	0.94***	0.94***
Y_{14}	0.42	0.44	0.55*	0.66	0.67*	0.70	0.58*	0.63	0.91***	0.91***
Y_{15}	0.32	0.40	0.53	0.78*	0.37	0.39	0.59*	0.64	0.78***	0.82***
Y_{16}	0.44	0.53	0.28	0.66	0.15	0.28	0.28	0.44	0.12	0.34
Y_{17}	0.13	0.36	0.33	0.63	0.23	0.57	0.37	0.45	0.07	0.23
Y_{18}	0.56	0.69	0.29	0.62	0.18	0.52	0.51	0.72	0.28*	0.36
Y_{19}	0.77***	0.83*	0.16	0.73	0.31	0.44	0.12	0.25	0.13	0.44*
Y_{20}	0.81***	0.85*	0.07	0.85**	0.46	0.51	0.16	0.18	0.20	0.47**
Y_{21}	0.48	0.69	0.33	0.40	0.25	0.57	0.09	0.46	0.23	0.31
Y_{22}	0.34	0.45	0.30	0.63	0.16	0.36	0.47	0.75	0.11	0.20
Y_{23}	0.53	0.59	0.38	0.75	0.41	0.61	0.26	0.60	0.12	0.28
Y_{24}	0.47	0.53	0.35	0.72	0.11	0.24	0.41	0.57	0.21	0.37

(1) $z = X_1, X_1^2, X_2, X_2^2, X_3, X_3^2$.

(r=0.33 to 0.55) by Cole et al. (1960); they reported also a positive correlation with carcass weight (r=0.52) and with total separable fat (r=0.33). In the next paper we shall discuss the relationships between loin eye area and weights of cuts (absolute values and their carcass percentages) and some biophysical characteristics (texturometer parameters, colour, chemical composition, pH, whose importance for objective carcass evaluation has been shown (Matassino et al., 1974, 1975 a, b, c; Cosentino et al., 1975)).

The carcass weight, total wholesale cuts and 1st quality cuts with live weight (X_1) and particularly gross live weight (X_2), agree with the efficiency estimate of Suess et al. (1966) and Romita et al. (1972). This estimate does not improve with multiple correlation $r_{Y_i.X_2X_3}$.

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VISUAL ASSESSMENTS

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Abstract

The variation in the numerous correlations published between visual assessments of live beef animals and carcass evaluations can be explained by differences in 1. the degree of variability of the material analysed, 2. the expertise of judges, and 3. the time interval between live assessment and carcass evaluation. Correlation coefficients decrease concomitantly with the variability of materials. My results demonstrate that visual assessment mainly evaluates the shape of an animal (weight per unit length), but fails to estimate portions of wholesale cuts.

Advantages of live visual assessment are its low cost and that it neither impairs the performance of the animal, nor its slaughter quality. The method is useful for the evaluation of cattle at the market when of great variability, but it is not sufficiently accurate for most experimental purposes.

Introduction

For centuries, visual - and to some extent tactile - assessments were the only means for selection in beef animal breeding. In spite of their inherent subjectivity, these criteria have been successfully employed in the establishment of large numbers of rather well defined breeds, differing widely in specialization and performance. The variability in special breeds and lines has indeed been minimized to such an extent, that still more refined breeding accomplishments can hardly be expected without resorting to objective evaluation. However, because of past success and low cost visual assessments will continue to be practised. It is the purpose of this paper to outline their usefulness and their limits.

All methods for the evaluation of meat-producting animals ought to fulfill a number of requirements.

1. The evaluation in the live animal should be closely correlated to carcass evaluation.
2. The accuracy should be sufficient to allow an adequate differentiation of the

characteristic assessed into categories within its range of variation.

3. The reproducibility should be high, both for individual and for different judges.
4. The procedure should not impair the performance of the animal or its slaughter quality.
5. The expense should be appropriate.

General aspects

Before exploring how closely these requirements can be met by visual assessments, some general aspects ought to be stressed:

The thick layer of subcutaneous fat prohibits any meaningful visual or tactile assessments in pigs. This holds also for high-grading beef cattle in the U.K., but not for the common West European beef cattle, which are most suitable for visual assessment.

The grading systems used commercially are not uniform. They are adapted to the local customs, which in turn govern the marketing practices. Factors which have to be taken into account by all systems are:

age,
sex,
state of health, and
degree of finish.

The age of cattle can be quite accurately determined by inspection of the teeth. The horn rings in older cows are a poor indicator.

Both age and sex are the major categories used to classify cattle, and definitions may vary considerably. Within each category it is then possible to subdivide, so that for steers in Germany, for example, the following subdivisions exist:

A: Young, very good conformation, high value, little fat
B: Young, very good conformation, high value, too fat
C: Little older, good conformation with full muscularity
D: Poor muscularity.

Most grading systems are restricted to healthy animals. Only minor disturbances might be tolerated, but usually result in lower grades. The evaluation of pregnant cows depends on the stage of pregnancy. Estimation of the contents of the alimentary tract is important in the prediction of the dressing percentage.

The degree of finish is essentially a function of age. It compares the appearance of the animal with the normally expected state of development.

Principles

The study commission of the European Association for Animal Production (de Boer et al., 1974) defined three characteristics for visual assessment.

Fleshiness - as the thickness of flesh relative to skeletal dimensions,

conformation - as the thickness of flesh and fat relative to skeletal dimensions,

muscularity - as the thickness of muscles relative to skeletal dimensions.

These properties are judged for the carcass round, loin, shoulder and occasionally for the brisket.

In the scoring system of the German Agricultural Society (DLG) a maximum of 50 points can be obtained:

		max. score	factor	max.total
A	overall impression	5	1	5
B	fatness	5	2	10
C	fleshiness			
	a. neck, brisket, shoulder	5	1	5
	b. loin	5	3	15
	c. leg	5	3	15
				50

Fleshiness is visually assessed, with exception of the musculus longissimus dorsi, which can be palpated in the kidney region. Palpation is also possible for the subcutaneous fat layer at the brisket, the throat, the shoulder, over the ribs, in the flanks and at the tail base. When drawing conclusions from the thickness of the subcutaneous fat layer on the amount of kidney and pelvic fat differences in breeds have to be considered. In beef breeds, the subcutaneous fat usually prevails over the intra abdominal fat, while it is opposite in dairy breeds.

Assessments of fleshiness and fatness are not freely transferable, but have to be seen in the context of market customs, categories, sizes, and weights. European judges will allow for some more fat to be present on a steer or a heifer, than on a young bull, and calves will be allotted a low quality rating without a minimum of fat. Bulls should be more heavily muscled than cows or steers, particularly with regard to the fleshiness of neck and shoulder, to qualify for the same grade of muscularity.

Correlation between visual assessment and carcass evaluation

The correlation between visual assessment and carcass evaluation has been the subject of numerous papers. Mason (1951) reported a correlation or r = 0.95 for the tactile assessment of the musculus longissimus dorsi versus the direct measurement and a correlation of r = 0.77 for visually assessed fat with carcass fat. Schön (1969) pointed out, that the amount of lean does not only depend on the fat content of the live animal, but also on the dressing percentage, which will increase with fat content. Bode (1964) found meat quality differences in animals which had received different grades. La Chevallerie (1968) cites correlations between live animal scoring and carcass evaluation ranging from r = 0.23 to r = 0.70. (Cook et al., 1951; Yao et al., 1953; Wheat and Holland, 1960; Davis et al., 1962; Weniger et al., 1965; Mach and Savodina, 1959). Lindhé (1966) graded live beef cattle in a cross breeding experiment. When their carcasses were graded again, 85 % received the same grade, thus the failure was 15 %. Woodward et al. (1954), Cartwright et al. (1958), Furthmann (1961), Gregory et al. (1962) and Schön (1963) reached few or no positive conclusions.

Results from our Institute demonstrate the tremendous influence exerted on the grading by the degree of homogeneity of assessed animals. Rappen (1962) obtained a correlation of r = 0.04 between live judgement and carcass evaluation on a subjective score scale for 28 young bulls from a beef cattle show. The animals were preselected by the producers and their variability, judged by visual assessment, was extremely low. A similar experiment with a group of less uniform animals (Witt et al., 1971) resulted in coefficients ranging from r = 0.55 to r = 0.86. The agreement of assessment in the live animal with that of the carcass thus tends to be the better the more pronounced the differences in appearance are. This is illustrated in more detail by our own results from a population of 394 bulls, 18 months of age, with an average weight of 557 kg and a standard deviation of 39.0 kg. In table 1 the correlation coefficients between the visual assessments of live bulls and their carcasses are summarized. The overall-correlation is r = 0.81, between the two scores for the round is highest at 0.84, and between the fat scores it is lowest at 0.45.
When correlated with carcass measurements (table 2), live visual assessment fares considerably worse. Round circumference is positively correlated with the live assessment, while round length even has a negative coefficient. Consequently in subjective judgement rounds of compact shape are preferred.

Table 1 Phenotypic correlations between visual assessments (scores) of live beef bulls and their carcasses (n = 394)

carcass	live animal (scores)					
	round	loin	shoul-der	fat-ness	over-all impr.	sum of scores
round	.84	.77	.71	.14	.80	.83
loin	.75	.75	.66	.10	.73	.76
shoulder	.70	.67	.66	.20	.69	.73
subc. fat	.08	.09	.18	.45	.18	.21
kidney & pelv.fat	.15	.19	.27	.45	.28	.31
overall impression	.69	.67	.66	.31	.76	.77
sum of scores	.74	.72	.70	.30	.77	.81

Table 2 Phenotypic correlations between visual assessments (scores) of live beef bulls and carcass measurements (n = 394)

carcass measurements		live animal (scores)					
		round	loin	shoul-der	fat-ness	over-all impr.	sum of scores
live wt. at slaughter	kg	.28	.20	.31	-.09	.24	.23
carcass wt. (cold)	kg	.34	.27	.37	-.11	.30	.30
carcass length	m	-.16	-.26	-.12	.04	-.19	-.19
leg circum ference	cm	.51	.41	.40	-.18	.39	.40
spiral leg measure	cm	.15	.07	.15	-.03	.11	.11
leg length	cm	-.33	-.37	-.23	-.04	-.32	-.34

Table 3 Phenotypic correlations between visual assessments (scores) of live beef bulls and carcass composition (n = 394)

carcass	live animal (scores)					
	round	loin	shoulder	fat ness	over-all impr.	sum of scores
kidney and pelvic fat %	-.05	-.02	-.15	-.28	-.09	-.13
omentum and mesenteric fat %	-.08	-.07	-.18	-.25	-.15	-.16
carcass wt. : carc.length	.50	.45	.50	-.15	.46	.44
round kg	.33	.25	.33	-.03	.30	.29
round %	.08	-.02	-.05	.18	.02	.03
round wt. round length	.55	.47	.51	-.02	.51	.51
round wt. round circumf.	.09	.06	.16	.06	.12	.11
lean:fat-ratio rib (9th-11th)	.03	.04	-.04	-.21	.00	-.03

The limits of visual assessment in the live animal are clearly shown in table 3. It is not possible to draw any conclusions from the relations between the scores and the quality of wholesale cuts (9 - 11th rib) or the quantity of intra abdominal fat, but weight/length ratios are in reasonable agreement.

The important correlation with the market price in table 4 also indicates that conformation can be reasonably well assessed visually in the live animal, while the judgement of fatness is problematic.

Of the five requirements mentioned before, three remain to be discussed.

The individual reproducibility of judgements has been investigated by Vitlo and Magee (1965), who arrived at correlation coefficients of r = 0.71 - 0.85 with intervals of four days. Davis et al. (1964) and Gregory (1962, 1964) found good agreement between experienced judges.

Impairment of the slaughter quality can be excluded for live visual assessment and can be avoided in live tactile assessment.

Table 4 Phenotypic correlations between visual assessment (scores) of live beef bulls and price per kg live weight (n = 394)

	live animal (scores)					
	round	loin	shoul- der	fat- ness	over- all impr.	sum of scores
price/kg live wgt.	.78	.72	.75	.17	.80	.80

The low cost of live visual and tactile assessment is undisputed and will keep this method with all its shortcomings in practice in the foreseeable future until objective procedures become available at a reasonable price.
There is, however, no doubt that for most experimental purposes live visual and tactile assessments are insufficient. Here, the higher cost of objective assessment is a minor factor in the overall expense.

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ESTIMATION OF BODY COMPOSITION IN VIVO, BY DILUTION TECHNIQUES

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ABSTRACT

The most promising method for in vivo estimation of body composition seems to be the dilution technique which consists of measuring body water by dilution of a tracer. It is possible to predict chemical composition of the animals, according to the close relationship between fat and water.

Different steps of this method are discussed : measurement of labelled water space, its relationship with total body water, and with empty body chemical fat.

Three methods for calculation of labelled water space are discussed. Labelled water space is closely related to total body water ($R > 0.90$), but overestimates it by 1 to 10 %.

Fat is the most variable component of body weight, but it is highly correlated with water. When empty body weight and empty body water are known exactly, the residual variability of fat is very low (3.3 to 8.0 % of fat weight). Thus labelled water space which is a good estimator of total body water is also a good predictor of fat (residual coefficient of variation varies from 4.2 to 14.0 %).

Prediction of fat can be biased by the variability of water in the gut content which varies with the nature of the food. It is therefore necessary to standardize feeding conditions of animals during the measurement of labelled water space.

Prediction of fat can also be biased by the variability of the fat-water relationship existing between animals of different breeds. A method of overcoming this difficulty is proposed.

Concerning this bias, it is not possible to measure accurately and in absolute terms, the body composition using the dilution technique, but it may provide a very useful means of classifying living animals.

INTRODUCTION

Estimation of body composition by tracer dilution techniques consists of measurement of body water by dilution of a tracer, and calculation of chemical composition of the body, according to the close relationship between chemical fat and empty body water. It is necessary to study the different steps of the method of estimation, before discussing its accuracy and its usefulness. These steps are :

- Measurement of tracer dilution space
- Relationship between this space and total body water
- Relationship between fat and body water (at the same body weight)
- Estimation of body fat from body weight and tracer dilution space

Numerous tracers have been used : urea, thiourea, sulfanilamid, antipyrine, N aminoacetylantipyrine, heavy water, tritiated water (see review of DUMONT, 1958). It is now accepted (DUMONT, 1958 ; PANARETTO and TILL, 1963 ; HAXHE, 1964) that labelled water (TOH or D_2O) is the more promising tracer of total body water. Therefore, we will limit our study to this tracer only.

DESCRIPTION OF THE DILUTION TECHNIQUE

Measurement of body water

After injection of the tracer into the blood, its concentration in plasma water (C) decreases with time (t) :

$$C = A_1 e^{-a_1 t} + A_2 e^{-a_2 t} \quad \text{(fig. 1)}$$

On a semi log plot, the curve becomes linear ($A_1 e - a_1 t \simeq 0$) after equilibrium of the tracer in the whole body water. Thus the rate of disappearance of the tracer ($a_2 = \frac{\Delta C}{C \Delta t}$) becomes constant within animals. Equilibrium is reached 2 to 6 hours after injection in sheep and 6 to 8 hours in cattle. The turnover rate (a_2) or the half life ($T = \log 2/a_2$) is variable between species : 3 to 5 days in sheep and 3 to 9 days in cattle (ROBELIN, 1973). Within species, a_2 depends on the water metabolism of the animal (water intake, temperature...).

The labelled water space (LWS) can be calculated by three different methods.

The first, which has been the most used, consists of measuring only the tracer concentration after equilibrium (Ceq). LWS is calculated as the ratio of the initial amount of tracer dosage (Q) and Ceq : $LWS = \frac{Q}{Ceq}$

This formula does not take into account the variations of turnover rate (a_2), which does vary between animals ; we have observed with lambs on the same diet (ROBELIN, 1975) that a_2 (expressed as % per hour) varied from 0.2 to 2.1.

Thus it is more accurate to calculate LWS from C_o, the theoretical tracer concentration at time 0. C_o is calculated as if equilibrium was immediate ; it is the intercept (A_2) of the second part of the curve (fig. 1). SYKES (1974) did not find any differences between these two methods of calculation of LWS, probably due to the fact that his animals were deprived of food and water during measurement. The turnover rate was certainly slower and its variability smaller. For normally fed animals, it is necessary to use the second method.

A third method is based on the theory of the dilution of a tracer in a two compartment system (AUBERT and MILHAUD, 1960). The calculation of LWS is more accurate because it is not assumed that equilibration is immediate. This method is very tedious because it is necessary to take a large number of blood samples (and to measure tracer concentration). The improvement of accuracy which is obtained is very small (ROBELIN, 1975).

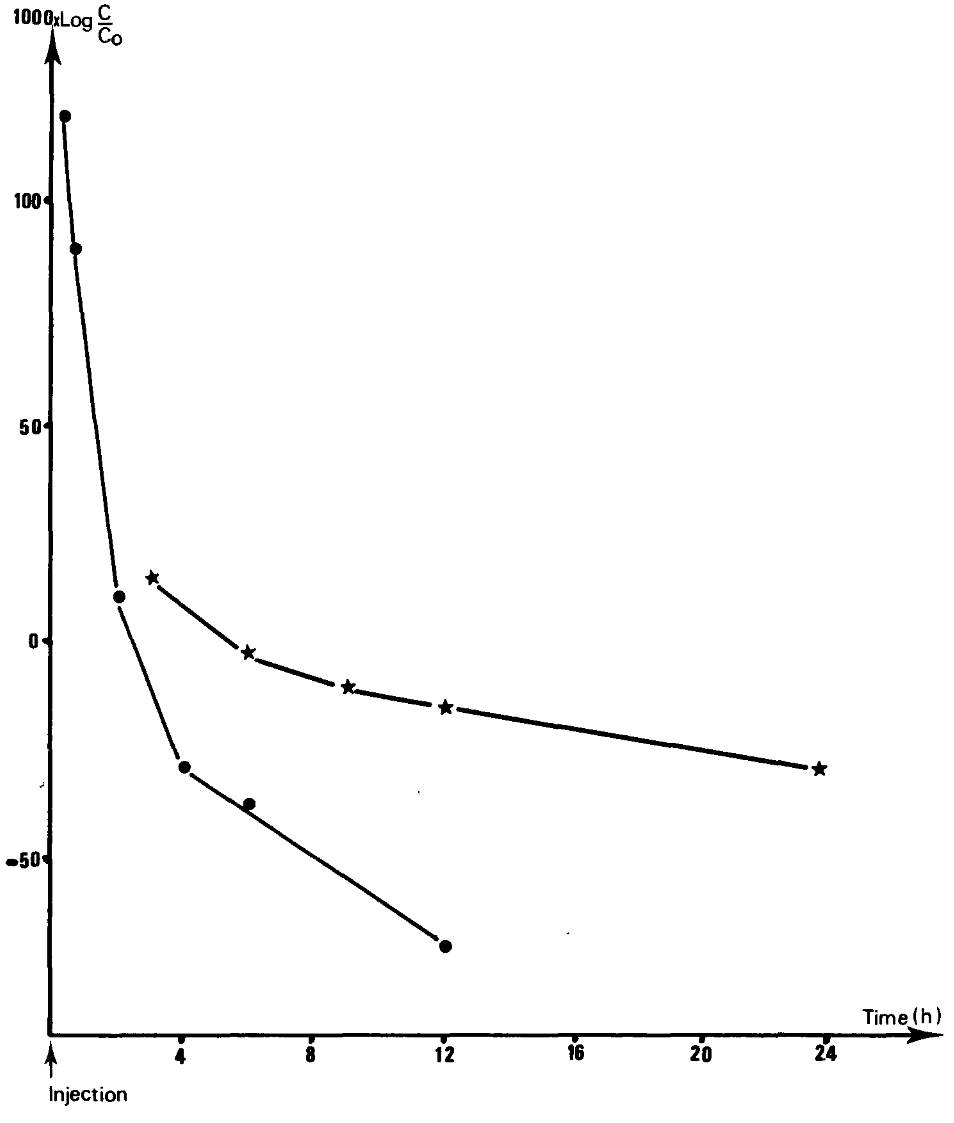

Fig. 1. Equilibration of D_2O in the plasma of lambs (●) and young bulls (*)
(C and C_o are the plasma water concentrations of D_2O respectively at time t and o)

Table 1

RELATIONSHIP BETWEEN TOTAL BODY WATER (TBW)

AND LABELLED WATER SPACE (LWS)

AUTHORS	Animals	Tracer	R (1)	RCV (2)
PANARETTO (1963)	9 Sheep	TOH	0.993	2.3
PANARETTO (1968)	15 Sheep	TOH	0.997	2.0
SEARLE (1970)	61 Sheep	TOH	0.997	2.4
FOOT and GREENHALGH (1970)	14 Sheep	D_2O	0.932	3.7
DONNELY and FREER (1974)	118 Sheep	TOH	-	2.7
ROBELIN (1975)	20 Sheep	D_2O	0.996	4.4
CANERGIE and TULLOH (1968)	26 Cattle	TOH	-	7.0
LITTLE and MORRIS (1972)	8 Cattle	TOH	0.994	2.8
CRABTREE et al. (1974)	12 Cattle	D_2O	0.922	4.2
ROBELIN (unpublished results)	9 Cattle	D_2O	0.984	2.4

(1) R = correlation coefficient

(2) RCV = residual coefficient of variation (residual standard error expressed as percent of the mean of TBW)

Relationship between labelled-water space and total body water

TOH or D_2O space overestimates total body water from 1 to 10 % (cf. review of ROBELIN, 1973 ; CRABTREE and al., 1974 ; DONNELY and FREER, 1974). This bias derives from the method by calculation of LWS (underestimation of initial concentration C_0) and from the exchange of the tracer with labile hydrogen of protein and lipids. Nevertheless, the correlation between LWS and total body water is very high ($r > 0.90$). The residual coefficient of variation (residual standard deviation as a % of the mean) is generally lower than 5 % (table 1).

Relationship between body water, and chemical composition at same body weight

It is well known that body composition is related primarily to body weight, or empty body weight by an allometric relationship. According to the results computed by REID et al (1968) on 221 sheeps, 88 to 96 % of the variability of weights of chemical components (water, fat, ash, protein) depends on the variability of body weight. The residual coefficient of variation (RCV) of the weights of water, ash and protein are lower than 5 % ; RCV of fat is greater (16.1 %).

The composition of lean body mass (empty body weight - weight of fat) is practically constant within species ; the percentage of water equals 77.0 in pigs, 74.9 in sheep, and 72.9 in cattle. Thus, when empty body weight and empty body water are known, the residual variability of fat is lower (RCV = 3.3 to 8.0 %) (table 2). This relationship is the basis of the estimation of body composition in vivo.

Relationship between labelled water space and weight of chemical components of the body

LWS improves significantly the accuracy of estimation of chemical fat from body weight alone (table 3). The residual coefficient of variation decreases from 11.4 - 27.5 % to 4.2 - 14.0 %. Figure 2 shows the good agreement between predicted fat and actual fat in 20 lambs. On the other hand, LWS does not improve the accuracy of estimation of protein or ash (DONNELY and FREER, 1974 ; ROBELIN, 1975).

Table 2 RELATIONSHIP BETWEEN FAT AND WATER AT THE SAME BODY WEIGHT : RESIDUAL VARIABILITY OF FAT

AUTHORS	Animals	Fat % Empty body weight	R.C.V. (1)
REID et al. (1968)	221 Sheep	4.9 - 46.6	4.9
SEARLE (1970)	61 Sheep	5 - 35	8.9
SMITH and SYKES (1974)	8 Sheep	-	3.9
ROBELIN (1975)	20 Sheep	6.3 - 14.2	7.0
REID et al. (1968)	256 Cattle	1.8 - 44.6	7.3
GARRETT and HINEMAN (1969)	48 Cattle	15.0 - 35.0	3.3

(1) RCV = residual coefficient of variation (standard error of fat expressed in percent of the mean)

Table 3 ESTIMATION OF WEIGHT OF FAT IN VIVO FROM BODY WEIGHT (BW) AND LABELLED-WATER SPACE (LWS)

AUTHORS	Animals	Tracer	RCV (BW) (1)	RCV (BW and LWS) (2)
SEARLE (1970)	61 Sheep	TOH	24.2	9.5
FOOT and GREENHALGH (1970)	14 Sheep	D20	-	4.2
TRIGG et al. (1972)	18 Sheep	TOH	-	9.1
SYKES (1974)	16 Sheep	TOH	20.2	13.8
DONNELY and FREER (1974)	118 Sheep	TOH	27.5	10.1
ROBELIN (1975)	20 Sheep	D20	11.4	8.4
LITTLE and MORRIS (1972)	8 Cattle	TOH	-	5.6
CRABTREE et al. (1974)	12 Cattle	D20	-	14.0

(1) RCV (BW) = residual coefficient of variation, when the independent variate is body weight alone (residual standard deviation expressed as percentage of the mean of fat weight)

(2) RCV (BW and LWS) = RCV when the independent variates are body weight and labelled-water space

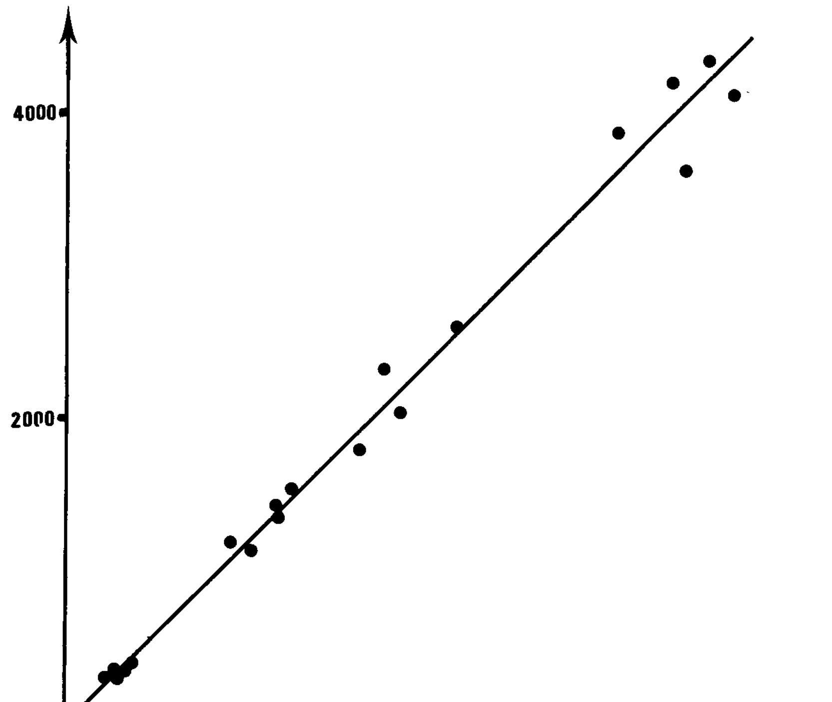

Fig. 2. Relationship between fat determined by analysis and fat predicted for lambs aged from 1 to 16 weeks

DISCUSSION ON THE USE OF THIS DILUTION TECHNIQUE

Nature of the tracer

Comparing different results obtained with TOH or D_2O (table 1 and 3), it seems that these two tracers are not significantly different. The difference in favour of TOH observed by TRIGG et al. (1972) can be attributed to the small number of animals and the measurement of D_2O concentration in plasma water. D_2O can be prefered to TOH, because it is not radioactive, but it is difficult to measure accurately its concentration in water. With a very good I.R. spectrometer, and 6 replications of the sample, the accuracy of measurement is 2.6 % (coefficient of variation) (ROBELIN, 1975).

This accuracy depends on the constancy of the sample temperature which could be improved by a self filling system.

Water in gut contents

D_2O space gives an estimate of total body water, including water in the gut contents which is variable. According to the results of BERANGER et al. (unpublished data) calculated on 201 cattle, the water in the gut contents (WGC) is related to body weight (BW), time after meal (T) and nature of food (NF) by the relationship :

$$WGC\ (kg) = 5.0 + NF + 0.12\ BW\ (kg) - 0.37\ T\ (h.) \quad SD = 11.4\ kg$$

At the mean body weight (541 kg), WGC was equal to 67,8 kg (12.5 % of BW), and the standard deviation of regression (SD) represented 16.8 % of that water and approximately 3.5 % of total body water. The effect of nature of food was highly significant ($P < 0.001$). The range of values of NF were from +24 kg for hay to -14 kg for a concentrate diet.

On 20 lambs, we have observed the same variability of the water in the gut contents (2.1% of total body water). This variability introduces an error in the estimation of fat. As it does not seem possible to estimate accurately water in the gut contents, it is necessary to standardise feeding conditions of animals in order to reduce the variability of water in the gut.

Variability of the relationship between fat and water

REID et al. (1968) showed that the percentage of water in the lean body mass decreased with age. DONNELY and FREER (1974) analysing the results of several workers have shown that on a wide age range with sheep, inclusion of the variate age improved significantly the accuracy of the equation for fat estimation. In this case both age and body weight reflected the nutritional history of the animals. On rapidly growing lambs (ROBELIN, 1975) it seems possible to use the same equation from 10 to 16 weeks of age (20 to 33 kg body weight). Certainly, it does not seem possible to use a general equation. It is necessary that certain characteristics of the animals, namely breed, sex and feeding regime or growth of the animals, be specified.

Accuracy of prediction

The residual coefficient of variation for fat is approximately 10 %. Thus, it is possible to demonstrate differences in the body composition between two lots of N animals, if this difference is greater than $\frac{30}{\sqrt{N}}$ % of the weight of fat (approximately 10 % for N = 10). The method can be used to classify animals into different groups at the beginning of an experiment in order to reduce the initial variability between groups or to reduce the number of animals used to obtain the same accuracy. It could also be used as a first approach to describe the relative evolution of the composition of an animal undergoing discontinuous growth (pregnancy, discontinuity in feeding conditions). It could be used also in genetic trials.

Lastly, the method could be used simultaneously with a direct post-slaughter technique. Suppose we have to measure the body composition of N animals. After indirect measurement of fat (using the dilution technique and appropriate equations) on N animals, we can measure exactly, by slaughter and chemical analysis, the composition of a sub-group (n) of the original N animals and using these, establish a relationship between the estimated (FE) and the actual (FA) value of fat:

$$FA = b\ FE + a$$

Thus it is possible to calculate from this relationship a best estimate of fat for the living animals.

As we have seen, the dilution technique cannot generally be used alone to measure exactly body composition in absolute terms. For accurate measurement of body composition slaughter and chemical analysis remains the best method. But, as the dilution technique is a good index of fatness and as it is used on the living animal, it is an interesting method for appraisal of body composition.

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DISCUSSION ON SESSION 2 ON "ASSESSMENT IN THE LIVE ANIMAL"
Discussion leader: E. Kallweit.

Questions on specific papers

With regard to Fisher's paper *De Boer* wondered whether making moiré-pictures was easier than in case of photogrammetry.
Fisher confirmed so, but added that for integrated measurements pictures from different sides are necessary as well.
Kallweit wondered how the position of the animal for making moiré-pictures was to be standardized.
Fisher explained that a normal stance of the animal should be achieved in the usual way by trial and error.
Concerning the paper by Bech Andersen two questions were raised. Answering a question by *Cuthbertson* on carcass composition *Bech Andersen* explained this is expressed in his experiments in terms of lean, fat and bone.
Kallweit wondered whether the correlation coefficients are the same for the muscle area assessed ultrasonically and in the carcass.
Bech Andersen explained they are similar in the case of the percentage pistol lean.
In the case of Robelin's paper *Kallweit* supposed some possible sampling error caused by stress of the animal and correlated changes in haematocrit values and blood volume.
Robelin explained this causes no error as blood sampling is only a means of collecting body water. Changes in the solid content does not affect the D_2O content in the plasma water which is the value required actually.

General Discussion

As a line for the general discussion the *discussion leader* proposed to deal with the methods in order of increasing technical and scientific effort: visual assessments, live weight assessments, ordinary measurements, ultrasonic measurements, dilution methods.
Carroll thought that Kallweit in his paper missed the point by comparing visual assessments in the live animal with those in the carcass, and not with compositional data.
Kallweit however pointed to the fact he did both.
De Boer stipulated that in particular types of experiments visual assessments

could be of much use, which is illustrated by some graphs on a fattening experiment with two genetic groups of Dutch Friesian bull calves. Consecutive fattening for veal and (after a reducing diet of hay) for bull beef shows consistent differences in fleshiness between groups in all stages. A main thing one would like to know in addition is the weight for length ratio of bones, for a better interpretation in terms of lean to bone ratio.

Kallweit concluded that visual assessments could be useful in case of large variations; they fail, however, when the variation is low, which is frequently the case.

Turning to l i v e   w e i g h t   d e t e r m i n a t i o n s the *discussion leader* raised the point of their accuracy.

Geay was of the opinion the assessment should be done all through the fattening period; the frequency will depend on the purpose of the study.

Kallweit wondered whether one could agree on weighing either right after the meal, or after a fasting period as applied in his institute.

Pomeroy pointed to the fact that gut fill not only depends on the type of food fed, but on water intake as well.

Geay stated that weighing right after the meal on two consecutive days did not show important influences of water intake.

Béranger observed that water intake with the feed influences gut content more than drinking of water, which disappears more quickly. In view of the great influence of the type of feed,weighing in a normal condition is to be preferred, as changes increase variation.

Hardwick suggested a different approach as internationally conditions could never be standardized. He would rather look for possibilities of correcting for well described experimental conditions.

Tayler first went into weighing under pasture conditions. In Hurley live weight on the first day of a stay in a new paddock proved to be high, but rather more variable; variation would be least in the middle of the days spent on a certain paddock. In short term indoor experiments (3-6 months) with different diets possible bias of live weight gain might be overcome by feeding a uniform feed during several days, fed in a fixed relation to body weight. In this way gut fill is stabilized. However, when systems of production are studied, differences of dressing out percentages are inherent to it and animals should be weighed in their normal state. The dressing out percentage assessed under these conditions is a thing one wishes to know.

Kallweit observed different points of view with regard to the moment of assessment of live weight and stressed the importance of giving adequate details on the method applied in the papers.

Fisher characterized standardization of measurements as the least promising aspect and is more in favour of imaginative research on this point. As views and methods are rather different, authors should define their measurements in the paper adequately.

Kallweit suggested that we accept the last recommendation.

Going on the ultrasonic and dilution techniques for assessing fatness *Cuthbertson* considered objective techniques necessary in view of inaccuracy of visual assessment. He pleaded for comparative work concerning different techniques, applied to the same animals.

Robelin pointed out that in France cattle have little fat and therefore ultrasonic assessment of fatness has not been considered useful so far. This may change as improved devices are becoming available. As far as dilution techniques are concerned he considered D_2O as the best tracer for cattle experiments.

Bech Andersen pointed to the use of combinations of techniques (e.g. ultrasonic measurement and dilution technique) which complement each other. He also pointed to the rapid recent developments in electronics, which allow considerable improvement of ultrasonic techniques, particularly in terms of objectivity. As a general point he stressed the importance of describing adequately the type of animals (variation in weight, fatness etc.) involved in the experiments.

Carroll, going into a question by the discussion leader, suggested that the ultimate reference basis of all measurements should be the proportion of lean, fat and bone in the carcass, and preferably their distribution.

Miles pointed to some aspects of ultrasonic technique, viz.

1. the different calibration of ultrasonic velocities in different devices, which is unnecessary;
2. the possibility of changing the frequency of oscillation in order to adapt to thin, cf. fat, animals;
3. the great potential of ultrasonics to replace radiation methods, without hazard, easy to use and relatively cheap.

Kallweit mentioned the variation in measuring points of the muscle cross section area.

Harrington suggested that those engaged in ultrasonic scanning of live cattle should try to measure the same thing. For this he would propose something like the lean and fat areas at the last rib, which measurements would of course have to be defined very precisely.

Bech Andersen considered the head of the last rib as most suitable, as it can easily be defined anatomically and because the shape of muscle is most regular at this point.

Cuthbertson agreed to this point, but prefered fat measurements both at 10th rib and last rib.

Kallweit concluded that most aspects of accuracy and standardization of methods have been dealt with adequately in the papers and the discussion, and brings the relevance of methods for different types of experiments into discussion. For breed comparisons etc. simple techniques will be rather limited, probably mainly for experiments on growth and nutrition.

Pomeroy agreed to that, because it comprises all tissues and all fat from the animal body.

Robelin, however, considered this indirect method not sufficiently accurate for application without a reference to a direct method (dissection, or grinding).

Béranger confirmed that in many experiments on nutrition and feeding precise methods are required, particularly with regard to fat deposition. On the other hand the dilution technique could be a useful tool in long term feeding experiments with different levels of feeding in consecutive phases. In addition this technique may be of use for classifying animals in the case of greater differences, e.g. in comparisons of breeds.

Bech Andersen suggested that the dilution techniques might be helpful as a tool for better allocation of animals to experimental groups, as an alternative to pre-experimental slaughter groups.

Harrington then reviewed briefly what could be usefully done further with regard to assessments in live cattle, stating that

1. visual assessments have low precision and are difficult to standardize. Further work in this repect seems useless;
2. ordinary measurements have low predictive value in terms of carcass composition. There is an EAAP recommendation on a set of reference measurements and no further efforts seem to be justified;
3. ultrasonic techniques are the only really promising field and further efforts should primarily focus on this aspect, particularly on questions of what to measure, and how (standardization);
4. dilution techniques are for use in specific cases only and for this reason international standardization aspects are not to be considered important.

Kallweit thanked Harrington for giving his conclusions, which may be somewhat too reserved in the case of dilution techniques.

Robelin thought that in the case of dilution techniques the conditions of use rather than the techniques themselves could usefully be standardized.

After briefly summarizing some main points the *discussion leader* closed the second session.

Part 3

ASSESSMENTS IN THE SLAUGHTERED ANIMAL AND ITS CARCASS

EEC Seminar on Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments, Zeist, 1975.

WEIGHT DETERMINATION OF THE CARCASS, INCLUDING FIFTH QUARTER AND EMPTY BODY WEIGHT

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A B S T R A C T

In this paper weight determination of the empty body and its components, fifth quarter and carcass, are discussed. A standardization of measurements within the different teams of research in the E.E.C. is proposed.

Empty body weight determination is useful for comparison of the carcass weight of different types of cattle. It can be obtained from the difference between live weight before slaughter and gut contents.

Carcass weight is definedaccording to the F.A.O./W.H.O. Codex Alimentarius. The possibilities of excluding some components are discussed and different problems in the determination of hot and cold carcass weight are presented.

Fifth quarter weight can be obtained from the difference between empty body and carcass weights. The determination of the weight of its different components is not always necessary and can lead to some errors. However some of these components can be of interest and their weight determination has to be made accurately.

INTRODUCTION

Determination of the weight of empty body components, the fifth quarter and especially the carcass, is fundamental both for professionals engaged in meat production or marketing and for investigators studying growth or feeding systems.

Therefore to promote intellectual or commercial exchanges it is essential to standardize measurement of these components.

1/ Empty body weight determination

Since the carcass dressing percentage interests economists, experimenters and butchers, different forms of expressing this are considered according to the objective pursued.

For economists, it is essential to relate the performances of living animals to results obtained at slaughter. The most commonly used dressing percentage (LIENARD G., personal communication) is therefore the ratio carcass weight/live weight. The live weight is measured before departure of the animal from the feedlot.

In contrast, buyers, butchers and research workers consider the carcass weight related to the live weight, measured just before slaughtering, when the animals have been transported and fasted for a certain period of time. This dressing percentage is then much more variable than the first. To obtain a measure of the animals butchery value it would be better to relate the carcass weight to the empty body weight. We noted in the earlier report the wide variations in gut content weight (from 10 to 20 % live weight, according to the diet). We can thus estimate the size of variation in dressing percentage for a given carcass weight. An animal with a 300 kg carcass and a 450 kg empty body weight will have a 500 kg live weight (50 kg gut content) if fed on kale , and its dressing percentage will be 60 %. An animal with the same carcass weight and empty body weight, if fed on grass hay (100 kg gut contents) will have a 54.5 % dressing percentage. If in addition to these causes of variation, the differences in fasting period before slaughtering are considered, it would appear difficult to identify the butchery value of animals by relating the carcass weight to the live weight before slaughtering.

Table I presents two carcass dressing percentages obtained on several breeds of bulls slaughtered at the same carcass weight. The first of these dressing percentages represents the hot carcass/empty body weight ratio; the second is the ratio hot carcass/live weight on day of slaughter. The live weight on the day of slaughter has been calculated by extrapolating the growth curve. Although the variations of the live weight due to fasting are excluded, it is clear that the carcass weight/empty body weight ratio provides a better differentiation of the breeds than the carcass weight/live weight before slaughter ratio.

The empty body weight can be determined by addition of the weights of the hot carcass and the fifth quarter components. It is important to avoid the risks of weight losses, due to the separation of the empty body's components and also to reduce the probabilities of errors following each weighing. In consequence, the empty body weight will be determined by the difference between the live weight before slaughter and the weight of the digestive contents. The latter will be obtained by the difference between the full digestive tract weight and the empty digestive tract weight.

It may be necessary to estimate the empty body weight of living animals from results obtained when contemporary and representative animals are slaughtered. The empty body weight (y) determination from the live weight (x) is possible using the following equation $y = a + bx$, based on data from previously slaughtered animals. A curvilinear equation is not necessary since the weight variation in most groups of slaughtered animals tends to be very low.

2/ Carcass weight determination

A definition of the carcass appears indispensable. A working party of the Study Commission on Cattle Production of the European Association for Animal Production represented by H. de BOER, B.L. DUMONT, R.W. POMEROY and J.H. WENIGER has

Table 1

TWO CARCASS DRESSING PERCENTAGES OBTAINED FROM DIFFERENT BREEDS OF YOUNG BULLS SLAUGHTERED AT THE SAME CARCASS WEIGHT

Breeds	Number of animals	Carcass weight (kg)	$\frac{\text{Hot carcass weight}}{\text{Empty body weight}}$	$\frac{\text{Hot carcass weight}}{\text{Live weight at slaughtering}}$
Charolais X Salers	128	316 ± 13	66,9	57,7
Normands	47	309 ± 14	66,1	56,2
Salers	267	314 ± 14	65,2	56,9
Friesian	45	304 ± 13	64,0	56,8

The live weight at slaughtering has been determined by extrapolation of the growth curve obtained by regression of weight on time.

proposed in 1974 a definition according to the F.A.O./W.H.O. Codex Meat (Alinorm 7417 - App. II) as follows. The whole body of a slaughtered animal either intact or split lengthwise in the approximate medial line of the vertebral column, after bleeding, skinning and evisceration, and removal of head, feet, genitals and udders of female animals that have calved. The head is separated from the carcass between the occipital bone (os occipitale) and the first cervical vertebra (atlas), the fore feet are separated between carpus and metacarpus and the hind feet between tarsus and metatarsus. In split carcasses the spinal cord is removed.

According to the inquiry held by the Cattle Commission of the European Association of Animal Production, it appears that 28 answers out of 38 were favourable to the separation of the forefeet as in fig. 2. Likewise, 27 answers of 39 were favourable to the separation of the hindfeet as in fig. 1.

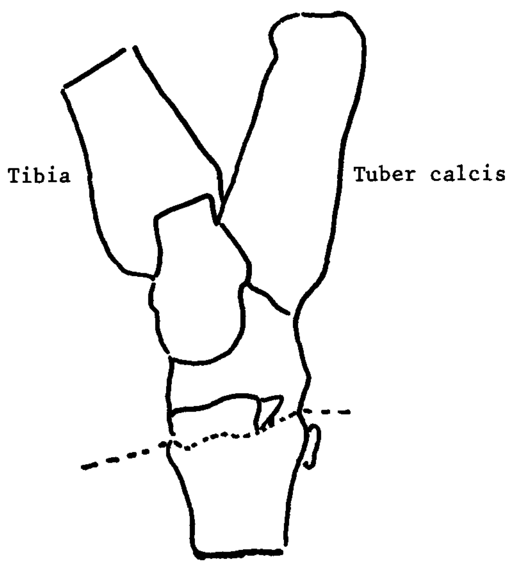


Fig. 1

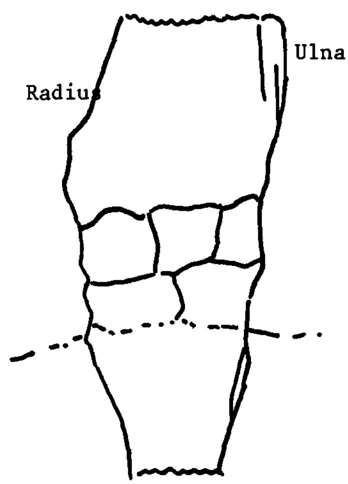


Fig. 2

This very valuable study also shows considerable heterogeneity in the separation of components of the carcass as defined previously, carried out by different research teams. Different commercial sales conditions require removal of certain carcass components : tail, lumbar part of diaphragm (pillar), costal and sternal parts of diaphragm, kidney and pelvic fat (perinephric and retroperitoneal fat). In order to make the comparison of results easier, it is therefore desirable to avoid any separation of the carcass before its weight determination. Alternatively, if general acceptance could be obtained, removal of certain components could be standardised, e.g. the tail, cut off leaving two coccygeal vertebrae on the carcass and the lumbar, costal and sternal parts of the diaphragm, which are easy to isolate. However, it appears essential that the carcass should include the kidney and the channel fat for their removal cannot be standardized and also that the subcutaneous fat should not be trimmed.

The hot-carcass weight must be determined immediatly after its preparation (within 60 minutes of slaughter). It appears desirable for the carcass to be prewashed since this is more hygienic than wiping with wet towels and reduces all carcasses to the same conditions of cleanliness.

The carcass weight determination by simultaneous or separated weighing of the two half-carcasses depends on the installation available. It seems, nevertheless, more accurate to weigh the two halves together.

During cooling, the carcasses lose some weight. This loss is a function of the temperature and the relative humidity of the chamber (FLEMING, 1970) and also of the speed of cooling (COOPER, 1970). Thus, according to the techniques which which were chosen, very wide variations of carcass weight loss were observed by SHEFFER and RUTOV (1970) (table 2).

3/ Fifth quarter weight determination

Fifth quarter weight can be determined in two ways : either by addition of the weights of the different components, or by substracting the carcass weight from the empty body weight. The latter method seems more advisable, because it

Table 2

INFLUENCE OF REFRIGERATION TECHNIQUES ON CARCASS WEIGHT LOSSES

(SCHEFFER and RUTOV, 1970)

Methods of cooling	Temperature of meat ° C		Air in chamber		Length of cooling h.	Looses of weight p.100	Cooling equipment of chambers
	Initial	Final	Temperature ° C	Speed m/s			
Ordinary	38	8	+ 4 / + 6	0.2 - 0.3	24 - 36	1.7 - 2.0	Spray diffusers and wet cold/store
Intensive	38	4	0 / - 1	0.5 - 0.8	20 - 24	1.6	Wet and dry cold-stores with distribution of air by slits
At two stages (ultra-quick)							
. cooling (1st stage)	38	10 - 15	- 10 / - 15	1 - 2	4 - 8	) 1.0	Dry cold stores with carcass ventilating or tunnel
. final cooling	15	4	- 1	0.1 - 0.2	6 - 8	)	Moderate circulation of air

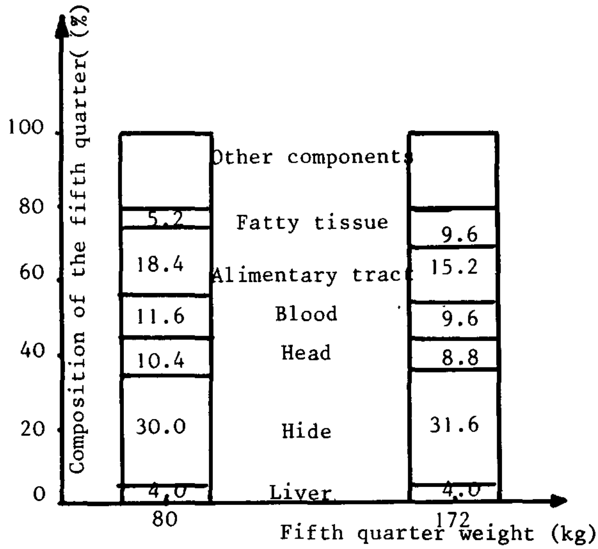


Fig. 3 Variation in the composition of the fifth quarter according to its weight in young Limousin bulls

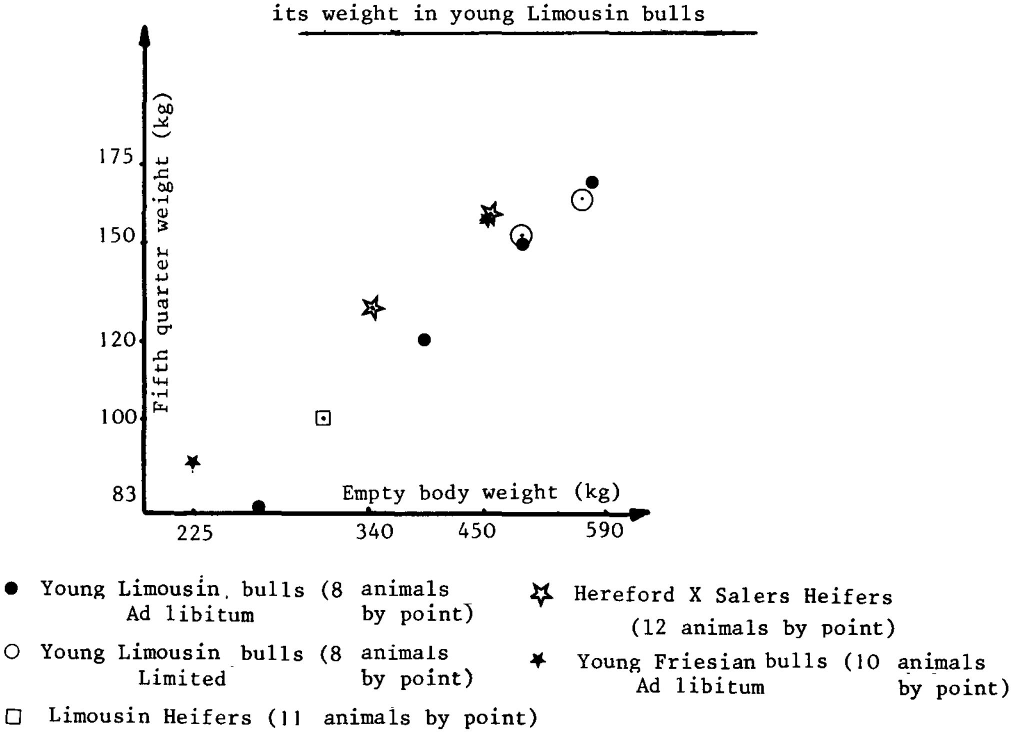


Fig. 4 Variations of the fifth quarter according to the empty body weight (in log coordinates) for different types of cattle

avoids errors due to weighing each component of the fifth quarter and the weight losses resulting from their separation.

Determination of the weight of individual components of the fifth quarter appears to be of interest because it permits detection of those that are particularly responsive to the factors studied : breed, sex or feeding levels.

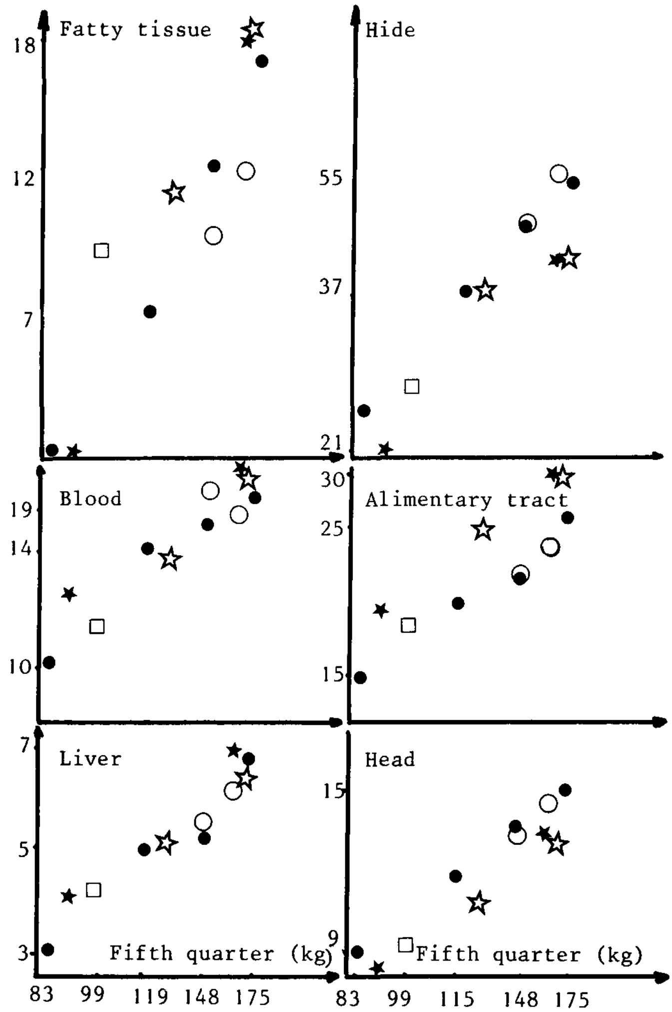
According to our results, six components represent in total, almost 80 % of the fifth quarter weight and this percentage remains constant when the fifth quarter weight increases (fig. 3).

One of these 6 components, the liver, represents a constant proportion of the fifth quarter and shows no variation with the breed, sex or feeding level (figs.3 and 5). Variations in the blood weight do not appear to be related to the various factors studied (breed, sex). The blood weight can be underestimated if the determination is made too quickly. It can be made either by subtracting the weight after bleeding from the live weight before slaughter or by direct weighing of the blood. The second method is certainly the most accurate, depending on the precision of the balance used for the total body weight determination, but its realisation is impossible in general slaughtering conditions. Also even if blood is not a negligible part of the fifth quarter its weight is not of great interest.

Finally, the weight of some components are responsive to the factors investigated and discussion of them should be of interest :

- The hide and head weights which represent, in total a constant proportion of the fifth quarter (fig. 5) differ according to the rate of maturing of the animal. The determination of their weight is quite simple and accurate. However, the hide has to be fatless.

- The fatty tissues and alimentary tract weights are responsible for the largest variations in the fifth quarter weight at constant empty body weight and therefore for the differences in dressing percentage (fig. 4 and 5) according to breed, sex or level of feeding.



● Young Limousin bulls Ad libitum ○ Young Limousin bulls Limited

★ Young Friesian bulls ☆ Hereford X Salers Heifers □ Limousin Heifers

Fig. 5 Variations of the weight of different fifth quarter components according to the fifth quarter weight for different types of cattle (in log coordinates)

Removal and determination of the weight of fatty tissues is not difficult. It appears much less easy for the alimentary tract which must be carefully cleaned. It is preferable to wash it and then weigh it 2 or 3 hours later rather than to take its weight just after emptying.

In conclusion, this paper did not intend to impose the best way of determining the weight of body components, but to review the different problems posed by this determination and to suggest some solutions. It is now necessary from the discussion of these suggestions, to formulate a common definition of carcass weight, fifth quarter weight and empty body weight.

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CARCASS SCORES, MEASUREMENTS AND INDICES

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Abstract

Three main purposes of a carcass classification are discussed. They should be to describe the carcasses in biological terms, to be a useful basis for pricing and to be a guide in beef production - mainly in breeding work. Carcass scores show from low to moderately high repeatability with the highest values for scores describing the whole carcass. Carcass measurements show high repeatability. Better definitions of how to take different measurement are, however, wanted.
Besides carcass weight different fat scores and fat measurements are the most valuable criteria to predict carcass yield. The degree to which fat criteria explain yield increases with the degree of fatness. Conformation scores and carcass measurements are only of marginal value. Some differences between sexes seem to exist. In bull carcasses the effect is somewhat higher than in other cases. Furthermore, thigh measurements normally contribute somewhat in the prediction of carcass yield but carcass length does not.
The residual standard errors in the prediction of total lean are on whole carcasses from 4 to 6 kg, which means big differences in economic value between carcasses of the same weight, fatness and conformation.

A classification based on conformation and fat groups in combination with a price system also favouring high carcass weight is described.

Introduction

The main purpose of measuring and scoring carcasses should be to evaluate them in terms of eatable meat and economic value. In other words, a grading or classification system should describe the carcasses correctly both from a biological and an economic point of view. However, what is accepted or appreciated (what is regarded as quality) varies from time to time, from country to country and even from district to district within a country. This makes it difficult or impossible to grade in terms of "quality", if the grading is intended to be of general application. A description of the carcasses in biological terms, on the other hand can be made much more general and thus be a basis for the payment to producers and for the wholesale and retail prices. Besides age and sex, carcass weight and degree of fatness seem to be the most important traits, while the value of carcass conformation seems to be overestimated. Furthermore, an important goal of a grading or classification system should be to supervise the production methods and the breeding planning (Brännäng 1966, 1967 and 1968 a).

In commercial classification it is difficult to use complicated methods and certainly not methods which lower the value of the carcasses. In experiments on the other hand this is normally possible, even if simple and cheap methods are also wanted here. However, features common to all systems of grading and classification are that they

1. can be done with good repeatability
2. are correlated with carcass yield and value and
3. can be a guide to the pricing systems as well as being used in the supervision during production.

Repeatability of scores and measurements

There is a rather extensive literature on this subject and the prevent review is not complete.

Skjervold (1958) studied the repeatability of scoring slaughter criteria on live animals. It varied from 0.26 to 0.49 for different parts of the body when using one judge and from 0.58 to 0.84 when using four. The score attempting to include the whole value of the animal (main score) had a repeatability from 0.61 - 0.77 to 0.86 - 0.93 respectively. Skjervold also studied the correlation between live and carcass scoring. For the main score they were 0.71 overall and 0.50 at constant weight. In a study of the quality of Swedish beef production the author (Brännäng, 1963) found that the accuracy of the fleshiness (conformation) scoring was good. Within breed the average scores, at the same carcass weight, were almost the same at different slaughterhouses all over Sweden. The scores increased, however, with weight. Up to about 300 kg carcass weight they increased by 0.5 - 0.6 units per 25 kg carcass weight but then levelled out. Within breeds no differences between sexes existed. (In Sweden all carcasses are classified since about 1940. The local classification is directed and inspected by the State Agr. Board).

Vial and Hennessy (1968) reviewed the literature on carcass measurements and also gave their own data. Both for live and carcass measurements the repeatability was high, on live animals from 0.826 to 0.978 and on carcasses from 0.960 - 0.996.
Dumont and Sornay (1974) used the measurements recommended by the EAAP working party (de Boer et al., 1974) on ten carcasses with a weight range from 247 to 548 kg. They found significant differences between observers for carcass length, for length and width of leg but not for chest depth. There were also significant interactions between observers and carcasses for some measurements. The errors decreased with repeated recording but the errors were still high for several measurements. They conclude that better definitions of how to measure and that better equipment are needed.
Generally it seems, however, that linear measurements can be taken with rather high accuracy. When trained judges are scoring even scores show rather high repeatability. Where visual assessment is used in commercial grading there is, however, always a risk of differences in levels between districts and variation from time to time which leads to some carcasses being wrongly priced if this classification system is used. This has been the case in the Swedish lamb classification in spite of the fact that standard photographs are used (Nilsson,1974 and 1975). Whatever the repeatability may be it is, however, only of academic interest if scores and measurements are not correlated with carcass yield and value - unless the only goal is just to describe the carcasses.

Correlation of scores, measurements and indices with carcass yield and value

Vial and Hennessy (1968) also studied the relation between carcass measurements and carcass yield and concluded that at constant weight all relationships between measurements and yield are meaningless. For example, the correlations between percent high priced cuts varied from 0.11 to -0.15, all nonsignificant. Between carcass depth and percent high priced cutsthe correlation was significant at the 5 % level but negative, -0.17. In all cases the correlations with eye muscle area were negative.
Martin et al. (1969) showed that carcass length was not correlated with percent trimmed prime cuts or percent lean. In a proposal for revision of the Canadian beef grading standards Fredeen et al. (1969) stated that conformation as indicated by actual measurements taken on the carcasses were of virtually no value in predicting total quantity of lean or the distribution of lean in the carcass.

Subcutaneous fat measurements and weight of kidney fat are often used to predict carcass value. Martin et al. (1969) found that average fat thickness explained from 29 to 45 % of the total variation in percent trimmed cuts and lean. Kidney fat only explained from 3 to 7 %. Cuthbertson (1974) reported that when using the subcutaneous fat thickness the standard deviation of percentage lean was reduced from 4.33 to 3.12 for beef carcasses and from 3.69 to 2.80 for lamb carcasses.

Crouse et al. (1975) reported that the individual trait most highly correlated (-0.76) with percentage cutability was fat thickness at the 12th rib and that this criterion is a valuable predictor of cutability in a population of carcasses regardless of their genetic origin.

Brännäng and Nilsson (1975) have, on different materials, studied the value of carcass weight, scores and measurements for predicting carcass yield. The residual standard errors in total lean, valuable cuts, fat tissue and bones as well as the degree to which the variation in them is explained (R^2) were calculated in a number of multiple regression equations. Some of the results are summarized in Table 1.

For the steers in sample A, fat and conformation indices improve the prediction only slightly compared with carcass weight alone. In the case of bull carcasses the effect is higher. When including fat score and average subcutaneous fat thickness in the equations the error of estimate for total lean decreases by 0.16 and 0.55 kg respectively. If the conformation score is added the errors decrease further or totally by 0.57 and 0.78 kg respectively. It is interesting to note that the thigh measurements on bull carcasses decrease the errors by about the same amount as the conformation score.

The partial regression coefficients for lean on thigh length were negative but positive on thigh circumference and index (index = circumference: length). Carcass length had no effect, but the partial regression coefficients were negative.

In material B, where the variation was higher than in material A, the subcutaneous fat (average of 2 x 4 measurements) was, in the case of bull carcasses, more useful in predicting lean and valuable cuts than the fat scores, but not in steer, heifer and cow carcasses. The explanation of this may be, that on fat carcasses with a more uneven fat distribution, a trained eye can evaluate total fat better than some single measurements. In the steer group in material A where the average of 2 x 13 measurements was used, the subcu-

Table 1. Percentage of variation explained and standard error of estimate on half carcasses for the prediction of the weights of total lean and valuable cuts in half carcasses. A. Crossbreeding experiment (n,bulls=57;n,steers =56),dissected. B. Commercial carcasses,Commercial boneless jointing (n, bulls = 76; n, steers = 28; n, heifers = 52; n, cows = 58). Sign. levels for the regressions: 0 = N.S., 1 $\leq$ 0.05, 2 $\leq$ 0.01 and 3 $\leq$ 0.001.

Independent traits	Total lean			Valuable cuts		
	R^2 x 100	S_e	Sign.	R^2 x 100	S_e	Sign.
A. Crossbreeding exp. (Upper rows of data from bulls, lower rows from steers)						
Carc. weight (CW)	95.8	3.57	3	94.3	1.41	3
"-	95.2	1.99	3	93.8	0.89	3
CW + Fat score (FS)	96.3	3.41	3.1	94.9	1.34	3.1
"-	95.4	1.95	3.0	93.9	0.90	3.0
CW + Sub.cut.fat (SCF)	97.1	3.02	3.3	95.0	1.29	3.3
"-	95.5	1.93	3.1	94.7	0.83	3.2
CW + FS + Conf.score (CS)	97.1	3.00	3.2.3	96.0	1.21	3.2.3
"-	95.5	1.95	3.0.0	94.3	0.88	3.0.0
CW + SCF + CS	97.5	2.79	3.3.2	95.9	1.22	3.2.2
"-	95.7	1.92	3.1.0	95.2	0.80	3.2.0
CW + SCF + Thigh circ. (TC)	97.5	2.80	3.3.2	95.8	1.23	3.2.1
"-	95.5	1.95	3.1.0	95.0	0.82	3.2.0
CW + SCF + Thigh index(TI)	97.5	2.80	3.3.2	95.3	1.29	3.2.0
"-	95.5	1.95	3.0.0	94.8	0.83	3.2.0
CW + SCF + Carc. length (CL)	97.1	3.05	3.3.0	95.3	1.30	3.2.0
"-	95.6	1.94	3.0.0	94.8	0.83	3.2.0
B. Commercial carcasses (Upper rows of data from bulls, 2nd from steers, 3rd from heifers, 4th from cows).						
CW	98.3	2.82	3	92.6	1.62	3
"-	90.8	4.00	3	65.4	2.62	3
"-	95.5	3.18	3	89.6	1.56	3
"-	95.1	4.43	3	91.9	1.74	3

Table 1. - continued

Independent traits	Total lean R² x 100	S_e	Sign.	Valuable cuts R² x 100	S_e	Sign.
B. Commercial carcasses						
CW + FS	98.5	2.68	3.2	93.5	1.51	3.2
"-	92.8	3.63	3.1	77.8	2.14	3.3
"-	97.9	2.17	3.3	92.9	1.30	3.3
"-	98.0	2.88	3.3	94.2	1.47	3.3
CW + SCF	98.9	2.26	3.3	94.6	1.39	3.3
"-	92.2	3.77	3.1	70.6	2.47	3.1
"-	97.9	2.20	3.3	91.9	1.39	3.3
"-	97.5	3.20	3.3	94.3	1.46	3.3
CW + FS + CS	98.7	2.47	3.2.3	94.6	1.39	3.3.3
"-	92.8	3.68	3.1.0	77.8	2.19	3.2.0
"-	98.2	2.06	3.3.1	93.0	1.30	3.3.0
"-	98.2	2.75	3.3.1	95.4	1.34	3.3.3
CW + SCF +CS	99.1	2.08	3.3.3	95.3	1.29	3.3.2
"-	92.2	3.83	3.0.0	71.0	2.50	3.1.0
"-	98.1	2.09	3.3.1	92.1	1.38	3.3.0
"-	97.6	3.20	3.3.0	95.0	1.39	3.3.2
CW + SCF + TC	99.1	2.10	3.3.3	95.4	1.28	3.3.3
"-	92.6	3.74	3.1.0	76.9	2.23	3.2.1
"-	98.0	2.17	3.3.0	92.1	1.39	3.3.0
"-	97.7	3.09	3.3.1	94.4	1.48	3.3.0
CW + SCF + TI	99.2	2.00	3.3.3	94.9	1.34	3.3.1
"-	92.3	3.81	3.0.0	71.4	2.48	3.1.0
"-	97.9	2.21	3.3.0	91.9	1.40	3.3.0
"-	97.7	3.11	3.3.1	94.3	1.48	3.3.0
CW + SCF + CL	98.9	2.27	3.3.0	94.7	1.37	3.3.0
"-	92.4	3.80	3.1.0	71.1	2.50	3.0.0
"-	97.9	2.18	3.3.0	91.9	1.40	3.3.0
"-	97.5	3.22	3.3.0	94.4	1.47	3.3.0

taneous fat was as good as the fat score in predicting total lean and valuable cuts.

In material B the effects of conformation score and linear measurements on the standard errors are small. In the bull group they are in most cases significant but not in the steer, heifer and cow groups. Even in this material carcass length was of no value in predicting total lean and valuable cuts. When carcass yield is given as boneless meat thigh length is negatively correlated with the yield but thigh circumference and index positively correlated. When correlating with cuts which have not been deboned,the signs are reversed. (Skjervold, 1958, Goll et al., 1961, Brännäng, 1968 and Martin et al., 1969). Through the partial regression coefficients it is possible to quantify the effects of different criteria on carcass yield. This is done for the different materials studied by Brännäng and Nilsson (1975). Yield of lean is regressed on carcass weight, fat score and conformation score. The results are given in Table 2.

Table 2. Partial regression coefficients for lean on carcass weight, fat score and conformation score (Whole carcasses).

Material (c.f Table 1)	n	Carcass weight kg/kg	Fat scores kg/score	Conformation score kg/score
A. Bulls	57	0.723^{xxx}	-4.285^{xx}	3.000^{xxx}
Steers	56	0.659^{xxx}	-1.959^{NS}	0.759^{NS}
B. Bulls	76	0.728^{xxx}	-1.486^{xx}	1.212^{xxx}
Steers	28	0.693^{xxx}	-3.941^{x}	0.283^{NS}
Heifers	52	0.640^{xxx}	-2.896^{xxx}	1.241^{x}
Cows	58	0.670^{xxx}	-3.504^{xxx}	1.176^{x}

Cuthbertson et al. (1972) found that at any level of subcutaneous fat, those carcasses with better conformation had about 1 % more lean than those of poor conformation. This corresponds closely with the results obtained from the Swedish material, except for bulls in material A where the effect of conformation score was higher.

Aspects of classification systems

De Boer and de Rooy (1971) used multiple regression to study the connection between fleshiness and fatness in a standardized scoring system and carcass grade (15 value classes with price intervals of H.Fl 0.10) and found multiple correlations from 0.5 - 0.7. One reason for this result was that the multiple correlation between weight and fleshiness and fatness scores was high - in the case of fleshiness scores from 0.4 to 0.7. Similar correlations are found in other studies (Brännäng, 1968 b). The importance of grade on carcass value (price per kg) is thus to a great deal indirectly due to an increase in carcass weight with grade. This was also the case in the old Swedish classification system (Brännäng, 1968 a).

The effect of conformation on grade is also evident. Using the thigh index, discussed above, it was found that correlations between this index and fleshiness scores were 0.4^{xxx} to 0.6^{xxx} for the Swedish Friesian (SF) and the Swedish Red and White Breed (SRB) respectively. The correlation between this index and hindquarter percentage were r = 0.03 in SF and r = -0.26^{xxx} in SRB, (Brännäng, 1968 b), but as discussed above this index is positively correlated with lean yield.

In an earlier study (Brännäng, 1963) it was found that at the same carcass weight, regardless of the score for fatness, SF carcasses received on average one score more for fleshiness than SRB carcasses which, in turn, received about one score more than carcasses of the Swedish Polled Breed. Therefore it was somewhat surprising to find that the percentage of meat and the meat:bone ratio, at constant fatness, for these breeds was the same (Brännäng, 1966, Brännäng and Nilsson, 1969). Similar results have also been published by Lindhé & Henningsson (1968), by Henningsson & Brännäng (1974) and by Butterfield and Berg (1974) concerning breeds and crosses of different conformation. Several studies also show low correlations between scores for fleshiness (or conformation) and meat yield at constant weight (Bech Andersen, 1972 and Cuthbertson, 1974).

These results are, however, mainly valid when comparing dual purpose breeds and British beef breeds. When Charolais with muscular hypertrophy and Limousin are studied these breeds have proved to be better valuedthan other breeds (Bergström, 1969, Dumont and Boccard, 1968).

The studies in Sweden on carcass evaluation led to a new classification system with four conformation classes (plus one for extremely poor carcasses and seven fat groups). The importance of conformation is now less than in the earlier days.

Standard pictures of the different classes are used (Statens Jordbruksnämnd, 1974). For young bulls and steers around 90 % of the carcasses are classified in the two best classes and for heifers and cows around 70 % (Sveriges Slakteriförbund, 1975). Furthermore the price difference between the two highest classes at present is around 0.15 Sw.Kr. per kg, and on average the same between weight groups (25 kg) up to 300 kg carcass weight. This means that 25 kg in carcass weight is equivalent, in monetary terms, to one class. The price differences between classes correspond closely to the results in material B (Table 2), as one class in the new grading system corresponds to about 2 old conformation scores. This means on average about 2 kg lean meat to a value of around 40 Sw.Kr. or 0.15 - 0.20 per kg.

Discussion

There is a great evidence that different conformation criteria contribute relatively little to the prediction of carcass value. At constant weight and fatness the decrease in standard error for total lean (calculated on whole carcass) varies from 0 - 0.8 kg and for valuable cuts from 0 - 0.3 kg.

The residual standard errors in the prediction of total lean are normally very high or in most cases from 4 to 6 kg on whole carcasses, which corresponds to differences in value between carcasses of the same weight, fatness and conformation of 100 Sw.Kr. or more. Efforts to improve the classification systems are thus of great importance.

Even if in general the effect of different carcass measurements is small there are some clear trends in the results. Carcass length seems to be of almost no value, whereas thigh measurements are somewhat better and show significant effects in several studies. Thigh length is negatively correlated with lean and thigh circumference positively. On a bone-in basis the signs are reversed.

The effect of degree of fatness on the prediction is evident. It is also evident that the higher the variation in degree of fatness in a study the higher is the value of an accurate fatness classification.

When comparing especially bull and steer carcasses there seems to be a difference in results. In bull carcasses conformation traits contribute more to the prediction of carcass value than in steer carcasses. This may lead to different conclusions depending on which type of material different authors have used. Breed differences may also influence the results. In the crossbreeding experiment, where purebred SRB were compared with crosses with SF, Aberdeen Angus, Hereford and Charolais, the coefficient from the regression of lean on conformation score (at constant weight and fatness) is reduced to 2.16 kg per score when the calculations are made within breed groups (c.f. Table 2).

Methods in carcass grading or classification should be a guide not only in the meat trade but also in production. The influence of the classification systems on the breeding goals is evident. Systems which clearly show the producers what is being paid for are to be preferred. The overestimation of conformation has in many breeds led to a selection for "beef breed" conformation, with calving difficulties as one undesirable consequence (Fagot 1964, Belic and Menissier 1968 and Menissier 1973). Muscular hypertrophy especially is associated with calving difficulties and other disturbances (Vissac, 1971). With this in mind it seems important that in carcass grading conformation is not given a higher weighting than it should have or in other words than what its real effect on carcass value is. It also seems likely that, with the growth of de-boning and fat trimming of primal or even of retail joints at the meat plant, the possible value of conformation to the retailer will decline (Cuthbertson, 1974).

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VISUAL ASSESSMENTS OF THE BEEF CARCASS

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ABSTRACT

Visual assessment is a cheap and convenient method of appraising beef carcasses but it suffers from a number of disadvantages inherent in most systems of subjective judgement. Some of these are obvious e.g. persons undertaking visual assessments must have had a great deal of experience, but others will be less obvious. Thus an important consideration is clarity of definition and it is essential to avoid combined assessments like 'shape and size of eye muscle'. Equally it is important to avoid quality judgements involving optima like "the correct proportion of fat" since different people will have different ideas as to where the optimum should lie.

Each characteristic to be assessed should be judged on a scale of marks of the same length i.e. 1 to 5, 1 to 7 or 1 to 10. A scale of 1 to 5 is probably too narrow for maximum discrimination and a scale greater than 1 to 10 is probably too wide for the majority of people to operate successfully.

Standards of assessment vary not only between assessors but also within the same assessor at different times. Added to this the assessment of a particular carcass is affected by the context effect i.e. the assessment is affected by the appearance of other carcasses in the same batch. These variations can be greatly reduced by the provision of visual aids like photographic standards.

VISUAL ASSESSMENT

Expert visual assessment is the least expensive and least destructive method of beef carcass appraisal. For this reason it is the technique commonly used in beef carcass grading and classification and in carcass competition judging. Possibly because of its essentially subjective nature it is usually considered to be too inaccurate to be useful as a research technique and the possibility of improving the accuracy and repeatability of visual assessment has been largely ignored. Nevertheless there are many occasions where the application of more objective and rigorous techniques of carcass assessment like whole or partial dissections is difficult if not impossible such as in genetic or nutritional experiments where it may be necessary to assess large numbers of carcasses in a short space of time. In these circumstances it may be that the only possible method of assessment is expert visual appraisal.

It must be admitted at the outset that even expert visual appraisal cannot be expected to achieve the same precision as objective appraisal as represented by carcass cutting and dissection. Since visual assessment is a subjective technique it will be affected by the idiosyncrasies, experience and subconscious prejudices of the individual assessor. There will, therefore, be variation between individuals assessing the same carcasses and within individuals assessing carcasses on different occasions. Nevertheless much of the criticism of visual assessment, for example, Buck (1963), Bray (1963) and Everitt & Evans (1970) is more a criticism of score-card or grading standards than of the accuracy and repeatability of visual assessment.

Williams (1969) investigated the efficiency of carcass competition score-card judging carried out by expert judges and pointed out that the efficiency of visual assessment can be greatly enhanced by improvements in definition of the carcass characteristics assessed. He found that there was considerable variation in the performance of expert judges using a traditional carcass competition score-card and he attributed this variation mainly to lack of precision in the definition of characteristics to be assessed, the presence of optima and the variable number of marks allotted to each item to be judged. Thus "quality, texture, marbling and colour of eye muscle" were all combined in the competition score-card and judged out of a maximum of 20 marks. This is a compound judgement of four separate characteristics and judges vary in the weight they attach to each in arriving at an overall score. In addition very few people can handle a total of 20 marks efficiently even for a well-defined characteristic. A total of 10 marks was allocated for "Depth of fat over Eye Muscle" but this allows for the expression of an optimum and carcasses may be awarded a low score because they have too little or too much fat in relation to a pre-conceived optimum which will vary from judge to judge. The total marks available for the different carcass characteristics varied from 5 to 20 and in addition to the difficulty of coping with 20 marks the judges clearly found difficulty in changing from one maximum to another.

In a second experiment Williams redesigned the score-card to eliminate ambiguities in definition and optima and all the characteristics were scored on a scale of 1-7 which was purely descriptive. When this was done there was a marked improvement in consistency of judgement.

The importance of accuracy and consistency of definition is clearly illustrated by the assessment of "conformation". Conformation is, in fact, very difficult to define but it is perhaps best regarded as the shape of the carcass. Many, if not most, meat traders associate a particular shape of carcass with a higher yield of high priced cuts and the United States Beef Grading Standards, for example, state "....... superior conformation implies a high proportion of meat to bone and a high proportion of the weight of the carcass in the more valuable parts". However, there is a move in the USA to reduce this emphasis on conformation. This idea of conformation as an indicator of the proportion of high priced cuts has been clearly shown to be erroneous. However, if conformation is regarded as an indicator of fleshiness i.e. the thickness of muscle plus fat, a further difficulty arises in that in cattle like the French Charolais which have very little subcutaneous fat, conformation is probably closely associated with thickness of muscle and probably with muscle:bone ratio. In British cattle, however, which are on the whole much fatter, a particular shape may be associated with thickness of muscle or with level of fatness. Thus, Harries, Pomeroy and Williams (1974) showed that the overall conformation scores awarded to beef carcasses by five expert judges acting independently were negatively correlated with percentage of lean (r = -0.35 to -0.51), positively correlated with muscle:bone ratio (r = 0.35 to 0.52) but also positively correlated with percentage of subcutaneous fat (r = 0.46 to 0.60).

There have been relatively few investigations into the efficiency of visual appraisal of carcasses and in considering the results of such experiments a point that must always be borne in mind is that it is impossible to carry out these investigations in such a way that the expert is not aware that his expertise is being subjected to critical scientific examination. He is, therefore, under stress even if he is not consciously aware of the fact and has every intention of being co-operative and, in consequence, his performance may be rather worse than it would be when he is carrying out his normal work in surroundings to which he is accustomed. On the other hand in some individuals performance may improve under stesss.

Some of the earlier experiments on visual appraisal of carcasses were those carried out by Gatherum, Harrington & Pomeroy (1959, 1960(a) & (b) & 1961) who investigated expert visual judgement of two characteristics of bacon carcasses, viz. the proportion of lean to fat in the surface exposed when the bacon side is cut across at the last rib and the shape and size of the gammon. All the judges in these investigations had not only had a great deal of experience in the bacon trade but also had had a great deal of experience in judging bacon carcass competitions where the score-card used included the above two characteristics. A point of considerable importance in relation to the visual assessment of carcasses generally which emerged from these investigations is what the authors termed the "batch" effect although, on reflection, it might have been better for the sake of clarity to have called it the "context" effect.

This is a general characteristic of visual appraisal and means that the assessment of an individual carcass is likely to be affected by other carcasses appearing in the same batch or group. Thus a somewhat overfinished or overfat carcass appearing among a group of underfinished carcasses will tend to be assessed as being considerably fatter than it really is. Conversely, an under-finished carcass appearing in a group of fat carcasses will tend to be assessed as leaner than it really is. The same principle applies to assessment of conformation.

This batch effect is of some importance in relation to national classification schemes for beef carcasses in countries like, for example, Great Britain where there is a wide variation in breed types and where particular breeds are locally dominant. Thus a Friesian carcass appearing in the North of Scotland where the Aberdeen Angus is predominant is likely to be assessed differently from what it would have been had it appeared in another area where there is a preponderance of Friesians. Gatherum et al showed that the batch effect could be greatly reduced by providing the assessors with photographic standards and both they and Harries, Pomeroy & Williams (1974) showed that the performance of novice judges could be improved by the use of such standards. It seems probable that, given a period of training in which assessments using photographic standards was supplemented by a feed-back of information derived from carcass dissections, the performance of inexperienced assessors could quite rapidly be improved to compare with experienced trade experts. However, this possibility does not appear to have been critically studied.

Harries et al found that, although the visual assessment of the subcutaneous fat content of the carcasses in their experiments was very good there was a curious tendency on the part of the judges to match the standards consistently to carcasses with a higher proportion of fat than those used for the photographs themselves although this did not materially affect the value of visual judgement in predicting fat content.

The photographic standards for subcutaneous fat produced by Harries et al covered a range from 4.1 to 16.6% of subcutaneous fat on a 7-point scale as is shown in Table I.

TABLE I

Photograph	A	B	C	D	E	F	G
Score	1	2	3	4	5	6	7
Percentage of subcutaneous fat	4.1	4.9	6.6	8.7	10.1	13.1	16.6

This range in subcutaneous fat percentage covers the range of subcutaneous fat normally encountered in commercial beef sides in Great Britain and the scale is logarithmic since it is readily apparent that small percentage increases in fat are more readily detectable in lean carcasses. A seven point scale was used throughout these experiments because the literature on psychology indicated that it was the most appropriate (Millar (1956)). However since the cattle in most European countries are notably less fat than in Great Britain the scale might possibly be advantageously extended at the lower end to make it a 9 or 10 point scale. Although it is arguable that in carcasses with less than 4% photographic standards are scarcely necessary as an aid to assessment.

Photographic standards as an aid to the assessment of fatness and conformation are being prepared for the Cattle Commission of the European Association of Animal Production. These are basically 5-point scales but each has been divided into three e.g. -1, 1+1, -2, 2+2 and so on so that, in effect, the scale consists of 15 points rather than 5. If, as is indicated in Table I, the weight of subcutaneous fat expressed as a percentage of the weight of the side covers a range of about 15 percentage points for European cattle generally, this means that the assessor is being asked to detect differences in subcutaneous fat equivalent to about 1% of the side weight. This might be possible at the lower levels of fatness but would be very difficult at the higher levels. Even if such discrimination could be achieved it must be remembered that, in cattle at commercial slaughter weights, the subcutaneous fat is normally only about one-third of the total fat in the side (subcutaneous plus intermuscular fat) (Pomeroy, Williams, Harries & Ryan (1974)) and that the ratio of subcutaneous fat to intermuscular fat is breed-dependant being greater in beef breeds than in dairy breeds. The importance of avoiding attempting the impossible in visual assessment can be well illustrated with reference to the distribution of lean meat between the high and low value parts of the carcass. This distribution does vary from one animal to another but the range in variation in the high value lean meat as a percentage of total lean is only about 2 percentage points. This means that in trying to detect difference in lean meat distribution in a side containing about 80 kg of total lean the assessor is looking for differences within a maximum range of about 2.5 kg and although this range would be commercially important it is virtually impossible to detect by eye. Nevertheless, many cattle breeders and butchers persist in the belief that they can assess visually, the proportion of lean meat in the expensive cuts and speak for example of an animal having "a high proportion of lean in the right places". This is a fallacy, they may well be able to assess thickness of lean or even muscle to bone ratio, and these may or may not be commercially important but they cannot assess distribution of lean.

In conclusion, visual assessment is a useful technique for assessing carcasses under commercial conditions providing its inherent limitations are recognised and providing adequate training backed by photographic standards is given to those undertaking the assessment.

Under research conditions, however, where precise measurement of carcass characteristics is usually necessary visual assessment cannot substitute for whole or partial carcass dissection.

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VISUAL ASSESSMENT OF CONFORMATION, FLESHINESS, MUSCULARITY AND FATNESS

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Abstract

The importance of clear starting points in visual assessment is stressed in order to make correct interpretations in terms of carcass composition. The morphologic characteristics represent the relative thickness of the fatty and muscular tissues. Quantification by scoring could be improved by the use of photographic standards, which internationally could serve as a reference basis. The question arises how this could be put into effect.

Definitions

As has been stressed by Dr. Pomeroy a clear definition of visually assessed characteristics is of utmost importance. The E.A.A.P. Working Party on beef carcass assessments (De Boer et al., 1974) has given definitions of morphologic characteristics involved, viz. of conformation, fleshiness, muscularity, fat covering and development of kidney and pelvic fat (Table I). They have been defined in terms of relative thickness, mainly to be derived from the shape of the carcass. This also limits to some extent the meaning of the word "shape" in this connection, although there remains room for different interpretation (Harrington, 1971).

Defining conformation, fleshiness and muscularity in terms of relative thickness should go along with defining the tissue groups involved. In the case of "flesh" the definition may look rather disputable; however it reflects the shape, or thickness, of muscle groups as it appears to the eye.

Table I. Definitions of concepts as given by the E.A.A.P. Working Party on Carcass Characteristics in Cattle.

Muscularity - thickness of muscles (= muscle fibres and intramuscular fat) relative to the dimensions of the skeleton.

Fleshiness - thickness of flesh (= muscle + intermuscular fat) relative to the dimensions of the skeleton.

Conformation - thickness of flesh and subcutaneous fat relative to the dimensions of the skeleton.

Fatness: fat covering - development of fat cover relative to the dimensions of the carcass.

Fatness: kidney and channel fat - development of kidney and pelvic fat relative to the dimensions of the skeleton.

It should be noticed that in very lean carcasses muscularity, fleshiness and conformation are identical; the characteristics diverge with increasing fatness by deposited intermuscular and subcutaneous fat.

Why the assessment of morphologic carcass characteristics

Describing carcasses in terms of relative thickness of tissue groups aims at deriving conclusions on carcass composition and realisation value (cutability), as cheap and practical methods of direct determination fail. Butchers and others in the meat trade make their conclusions on the amounts of excess fat and bone and on the amount and quality of saleable meat in this way. In many experiments the most important aspects relate to the proportions of muscular tissue, fatty tissue, and bone, and their distribution.

In several experiments morphologic characteristics are of interest in themselves, in particular muscularity. It may be important to determine the potential muscularity of animals, strains or breeds, and to be able to assess this characteristic discriminatively.

It seems important that visual assessment should refer as much as possible to directly perceivable traits. For example muscularity cannot be assessed directly in the rather fat carcass; fleshiness is the perceivable characteristic to be recorded, even though judges might be able to estimate muscularity directly by taking account of fatness. There is good evidence (e.g. Harries et al., 1974) that experienced classifiers are able to estimate visually the percentage of subcutaneous fat quite accurately, probably by taking into account both the layer of subcutaneous fat and the thickness of underlying flesh. In such cases the weighting of components contributing to the overall estimation is done during the judging, and hence in a way which may not be easy to test.

In using morphologic characteristics for the prediction of carcass composition or carcass cutability two main aspects prevail, viz.

1. the accuracy and standardization of the visual assessments
2. the interpretation of the assessments and their quantitative relation to portions of tissues or cuts.

The accuracy and standardization of visual assessments

The morphologic carcass characteristics refer to relative dimensions and shapes and cannot easily be referred to objective identities of a similar nature. For this reason one must resort to photographic standards as a reference basis and to repeated or parallel judgements for checking the accuracy of the assessments.

At the international level the O.E.C.D. and later the FAO/WHO Codex Committee on Meat (Alinorm 74/17), and the E.A.A.P. (De Boer et al., 1974) have established standards for quantitative carcass characteristics. In the E.A.A.P. Working Party extensive sets of photographic standards (colour slides) have been prepared.

There is no doubt that photographic standards are a most useful aid in visual assessment of carcass characteristics. There is no doubt either that experience in the application of the standards is also essential for achieving meaningful results, as the paper by Harries et al. (1974) confirms.

Some results of repeated and parallel assessments of "fleshiness" and "fat covering" are given in Table II, in order to discuss aspects of consistency and discrimination. In this case (De Boer et al., 1973) a 6 point scale was applied, with a subdivision of each class into three (+, 0 and -), making 18 subclasses for both characteristics. A series of 98 colour slides of carcasses was judged with long intervals; a special test showed that results were similar to parallel judgements in real carcasses.

Statistically the results may be expressed as various test values to characterize uniformity of judgement. There is no statistical criterion, however, for deciding on the acceptability of the system of differentiation.

In this case one might conclude from Table II that the high degree of differentiation (18 subclasses) is not of use as in only 20-40 % of the cases the scores are identical with the "standard judgement". However, the economic impact is a factor as well. In the case of "fleshiness" each subclass (1/3 class) involves a difference in value of 0.15 to 0.20 Hfl per kg, or about 45 Dutch guilders per carcass. From this point of view less differentiation seems unacceptable for evaluation of individual carcasses.

Table II. Comparisons between independent test scorings of diapositives by 3 persons.

Deviation from real carcass score	F L E S H I N E S S									F A T C O V E R I N G								
	Person L			Person R			Person N			Person L			Person R			Person N		
	70	71	72	70	71	72	70	71	72	70	71	72	70	71	72	70	71	72
1 1/3 lower				1		1					1		1	2				
1 lower			1	4		4				1	1	4	1	2	4			1
2/3 lower	3		6	16	1	15	2		2	9	6	8	4	8	6	1	7	9
1/3 lower	17	15	24	26	18	28	15	13	10	18	12	20	16	12	13	19	12	13
identical	32	34	37	29	31	19	43	43	42	32	23	24	25	24	27	19	26	27
1/3 higher	36	30	19	15	29	19	31	32	28	23	27	17	23	21	19	30	27	19
2/3 higher	10	16	11	7	15	12	7	10	12	13	18	18	14	21	16	24	18	14
1 higher		3			4				4	1	6	2	11	4	9	4	8	10
1 1/3 higher										1	3	5	2	4	1	1		4
1 2/3 higher											1		1		3			1
total	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98

In the case of fat covering the difference in value between adjacent subclasses is less, and moreover the discrimination is less consistent than in the case of "fleshiness". Hence for fat covering a less differentiated scale would do.

This conclusion seems contradictory to the one by Harries et al. (1974). As will be explained later, different starting points are involved.

Implications of morphologic characteristics

For a given weight thick carcasses (good conformation) must have shorter dimensions than poor conformation carcasses; that is, they have shorter bones. If thickness is due to fat deposits it is logical and evident that bone weight in per cent of carcass weight is consequently low. The same holds, however, when thickness is due to thick muscularity, coinciding with short bones relative to muscle weight. As a rule the shorter bones will be less heavy, resulting in a high muscle to bone ratio in heavy muscled carcasses. Sometimes, however, breed differences in bone weight per unit length may interfere; in Jersey carcasses for example a favourable muscle/bone ratio is due to relatively thin and light bones, and not to thick muscles (Bergström, 1974, p.116). There seems to be no reason, however, to raise the

exceptions to a rule, as Harrington does (1971). On the whole thick muscularity goes along with a high muscle to bone ratio and differences of 10 % (e.g. 4.4 versus 4.0) may easily occur between diverging degrees of muscularity. Such differences result in differences in muscle content of about 2 % in carcasses of similar fat content. However, thick muscularity also interferes in the interpretation of the morphologic characteristic "fat covering" in terms of fat percentage in the carcass.
Several years ago we tried to quantify these relationships in a diagram, of which Table III makes part.

Table III. Supposed relation between fleshing score and carcass composition within class 3 (scale 1-6) for fat covering.

Components	fleshing score					
	1	2	3	4	5	6
Approx.% musc. tissue	56.0	60.2	62.5	65.0	67.0	69.5
" % fatty "	21.5	19.2	17.8	16.3	15.0	14.0
" % bone "	18.5	16.0	14.8	14.0	13.2	12.5

A similar table published by I. Schön (1975) suggests a similar progression of the percentage of muscle with increased conformation within a class (score) of fat covering. The quantitative relations between classified morphologic characteristics are not well established, however. Moreover they will not be linear, as indicated by the M.R.I. figures on the relation between fat scores (1-7) and the percentage of subcutaneous fat in the carcass (Harries et al., 1974).
The implications of fleshiness and fat covering with regard to muscle/bone ratio and fat content of the carcass may be summarized as follows:

1. The extent to which a certain degree of fleshiness is due to muscularity must be derived from some measurement or estimate of fatness. High muscularity will normally give high muscle to bone ratios.
2. At a particular degree of fleshiness differences in fat covering will go with differences in percentage of subcutaneous fat. At different degrees of fleshiness, however, similar fat covering will correspond with lower percentages in thicker fleshed carcasses.

When fat covering is not expressed morphologically, but as a percentage of subcutaneous fat, the assessment of fleshiness will only be able to contribute to the prediction of carcass composition as far as bone is concerned.

Interrelationships of characteristics

The use and interpretation of morphologic characteristics encounters difficulties not only through their very nature but also through the interrelations between the perceivable characteristics themselves and between them and weight. In order to visualize some relations data on big samples of adult slaughter cows and heifers of the two main Dutch breeds have been plotted in figure 1. The red and white MRIJ cattle are heavier and more muscular than Dutch Friesians. The samples are representative of the Dutch supply of slaughter cattle in 1969.
The figure 1a shows that the carcass weight is higher at higher degrees of fleshiness (and correlated increased fatness). In the case of adult cows, where differences in size of skeleton do not interfere very much, the carcass weight in both breeds is similar in the same fleshiness class, indicating that the difference between the breeds is made up mainly of their fleshiness. One might also think that in cow carcasses weight might be an objective substitute for the criterion fleshiness. However, considering the economic impact of one class difference in fleshiness (about 0.50 Hfl), the weight intervals between classes of fleshiness (25 to 30 kg) and the standard deviations of average weight within fleshiness classes (about 25 kg), the conclusion must be this is not sufficiently accurate for evaluation of individual carcasses.
As a matter of fact the weight criterion does not work either as a criterion for comparing breed groups in respect of fleshiness, as shows figure 1c. At the same level of fatness distinct differences in fleshiness between breeds occur within weight classes, which are greater at the higher weight levels. From the figures it could be concluded that the best starting point for comparing genetic groups with regard to muscularity is the comparison at the same level of fatness (figure 1e). On average the breed differences seem to be rather independent of the level of fatness. Comparison within fatness classes has the advantage of bringing about a minimum of complications in the interpretation of fleshiness in terms of muscularity. In addition it will comply with practical conditions, where degree of finish is most decisive for sending cattle to slaughter.

Starting points have important effects on conclusions reached

Visual carcass assessments have brought about a lot of discussion on their merits. When fatness is assessed in terms of thickness of fat covering it seems reasonable to have thickness of flesh as a second criterion. For deriving the percentage of subcutaneous fat, as a measure of total fat, both criteria are

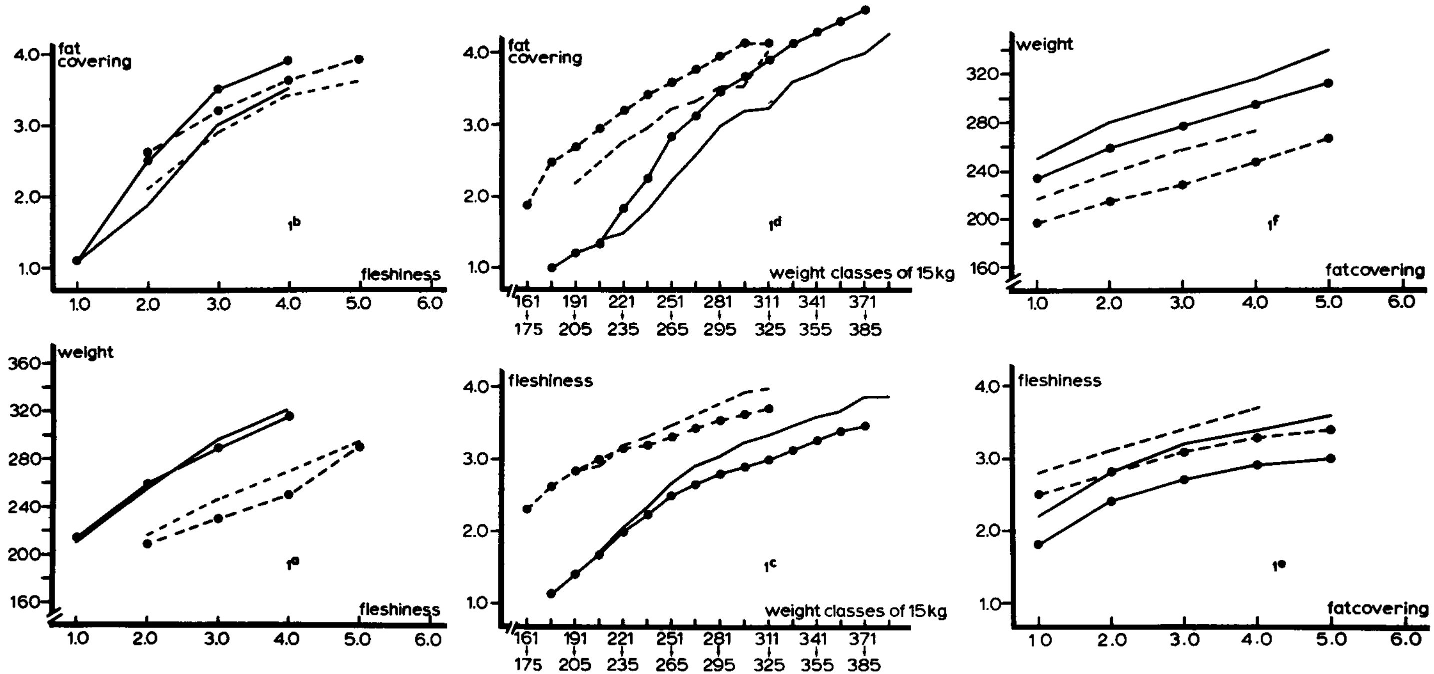
Fig. 1. Relations between fleshiness, fatness and carcass weight in samples of heifers and adult cows representing the Dutch black and white (Friesian) and red and white (MRIJ) breeds (1969).

●- - - -● black and white heifers, age group 1½ - 2½ years (N = 6043)

- - - - - red and white heifers, age group 1½ - 2½ years (N = 1146)

●———● black and white cows, age group 5 - 9 years (N = 6909)

——— red and white cows, age group 5 - 9 years (N = 2358)



required. In addition thickness of flesh gives an indication of the lean to bone ratio.

In the case of the material of Pomeroy et al. (1974) the analysis by Harries et al. (1974) did not show a clear contribution of "conformation" to the prediction of carcass composition. The results seem quite understandable, however, because "fatness" in this case was assessed - succesfully - as the percentage of subcutaneous fat in the carcass. This being so leaves little room for a contribution of the characteristic "conformation" to the prediction of the lean/fat ratio. The only remaining possibility could be a contribution to the prediction of bone content, or the muscle to bone ratio. This comes out indeed (correlation 0.35 - 0.52) and the correlations are almost identical to those between estimated muscle/bone ratio and the muscle/bone ratio determined by dissection, indicating what the judges may have understood by "conformation".

The same kind of objections are valid for the correlations between conformation and traits of composition, calculated by Cuthbertson (1974). For a given percentage of fat the predictive value of conformation,or fleshiness, or muscularity with regard to lean/fat ratio should be zero.

It may be that the estimation of subcutaneous fat as a % of the side weight works as well as the assessment of fat covering in terms of thickness. Particularly for experimental purposes, however, it seems necessary to choose a clear starting point, the one or the other. In the first case percentages of subcutaneous fat should form the reference basis, in the second case photographic standards characterizing the thickness of the fat layer overlying the muscles and irrespective of their thickness.

As an aid to the estimation of the percentage of subcutaneous fat a series of photographic standards will only apply to one particular class of fleshiness. If judges are not clearly instructed on this aspect results may be difficult to interpret.

Some final considerations

The use of visually assessed carcass characteristics should mainly be justified as a means of predicting carcass composition. In addition they may describe other properties of the carcass which are important to the meat trade and butchers.

As long as visual assessment is generally used as a basis for carcass payment it should not be neglected in beef production research in view of the economic interpretation of data.

Visual assessment may aim at quantifying characteristics in a morphologic sense (relative thickness of muscles and/of fat) or at the direct estimation of percentages. It is necessary to draw a distinction between these two starting points.

The relations between morphologic carcass characteristics and carcass composition in terms of muscle, fat and bone are not yet well established. The use of well defined concepts and standards is of primary importance in this respect.

Photographic standards for visually assessed criteria of muscular development and fatness are a most useful aid for classifiers. Standardisation of the routine involved is as important, however, for obtaining accurate results.
For achieving comparability of results at the international level the use of some common scoring table seems difficult because of the lack of a sufficiently standardised routine. It would be preferable to relate commonly used scoring systems to the international reference standards, provided principles are identical.

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DISCUSSION ON SESSION 3 ON "ASSESSMENTS IN THE SLAUGHTERED ANIMAL AND ITS CARCASS"
Discussion leader: B.L. Dumont.

General Discussion

At the beginning of the general discussion the series of colour slides, representing the E A A P s t a n d a r d s for fleshiness and fatness (fat covering) respectively, were demonstrated by *Dumont* and *Williams*. The complete series of fleshiness standards comprised 8 positions per carcass in each sub class (1-, 1.0, 1+ etc. up to 5+), totalling to 120 slides. The series of fatness standards included 15 lateral views of carcasses in each of the sub-classes. Full reference to these series is given in the paper in Livestock Production Science 1 (1974):151-164. *Williams* and *Cuthbertson* thought that the series on fatness is not yet quite satisfactory in the presentation of the successive steps. *Carroll* considered that the beginning and the endpoint of the scale were appropriate and that subdivision is a matter of filling in and correction eventually. *Pomeroy* observed that in the carcasses in the higher end of the scale the percentage of subcutaneous fat increases with increasing score. Visual differentiation is difficult, however, in this range. *Williams* was of the opinion that the actual degree of differentiation (15 subclasses) is too high.

Questions on specific papers

Dumont then opened the discussion on individual papers and the evaluation of methods in terms of

1. accuracy, ease of application, and costs
2. suitability to different kinds of experiments
3. further improvement.

Lykke doubted whether v i s u a l c a r c a s s a s s e s s m e n t is really valuable in view of the increasing importance of selling cuts instead of carcasses. There is a need for objective methods and in Denmark work has started on similar lines as in pig carcass classification with the KS-meter, including lateral measurement of thickness of long. dorsi and of the fat over it. Preliminary results seem promising. *De Boer* underlined the importance of this approach, but was not convinced by the quoted low correlations between conformation (or fleshiness) and lean content, because fatness interferes.
Harrington wondered whether it makes much difference to use fat thickness or

a percentage of subcutaneous fat. In the MLC many calculations have been made on the importance of conformation within weight and fatness classes (which showed a broad range).

De Boer stressed that carcass weight depends on 3 factors: carcass dimensions, thickness of muscles and thickness of fat. The variation of individual factors will very much determine results of calculations.

Dumont suggested that a strong recommendation should be made on the assessment of c a r c a s s w e i g h t. *Geay* thought that the weighed carcass should be in its most complete form. In addition to the EAAP and FAO/WHO Codex-recommendation a line of separation of the feet should be given.

Mrs. Schön thought that in this report the Codex-recommendation is the same as that proposed by Geay.

Carroll pointed to the importance of trimmings from the neck, removing fat and blood vessels. He thought a final decision on a recommendation requires some further consideration as yet. He also raised the point of washing the carcass before weighing; the discussion resulted in the conclusion that this should not be done before weighing of carcasses involved in experiments.

Williams considered that a uniform procedure is not attainable and recommended reporting of the methods followed in publications. To this, however, *Dumont* did not agree as the problem of carcass weight seems most simple and soluble.

Hardwick considered it desirable to quantify the influence of the disputed points involved.

With regard to the weighing of t h e 5th q u a r t e r *De Boer* raised doubt on its relevance in many experiments. *Béranger*, however, pointed to effects of breeds and stages of growth and thought it should be included in experiments of this kind. In feeding experiments the determination of intestinal fat might be sufficient. *Robelin* stressed that in experiments based on chemical determinations whole body analysis is necessary, including the organs themselves. *Bech Andersen* considered inclusion of the 5th quarter important, because 40 % of the feed supplied is involved.

Carroll suggested that one should focus on the relation between total gut content and the one of the forestomachs, in order to be able to confine oneself to weighings of empty stomachs. *Béranger* agreed that the rumen is the main source of variation and thought that analysis of data of the INRA Centre of Theix could give data on this important question.

In spite of *Lykke*'s statement on an alternative to v i s u a l a s s e s s m e n t it was concluded that the latter remains necessary as yet.

Harrington considered the situation in this respect quite clear: visual assessments can easily be done as part of any experiment and we have good EAAP standards now which should be applied in order to improve comparability of results. Moreover more than anywhere else standardization is attainable in this respect. *Dumont* concluded that application of the standards in all types of experiments is desirable, which enables subsequent analysis of the relations with carcass composition and carcass value. *Carroll* supported the idea of checking visual asessement of fleshiness by subsequent cutting up of the carcasses, to which the standards give a sound basis. *Hansson* had doubts on the use of the high degree of differentiation in scoring, which was based on the poor relationship with cutting results found in Swedish investigations and on difficulties in maintaining standards during quick routine classification. The "context-effect" mentioned by Pomeroy is also an aspect of this. *Dumont* and *Pomeroy*, however, did not regard a high speed of classification as a problem. In closing the discussion *Dumont* mentioned as the main aspects of agreement on common procedures, the determination of carcass weight and the use of the EAAP standards of "fleshiness" and "fatness". *Carroll* expressed thanks to Dumont for providing the magnificent set of colour slides representing the EAAP standards of fleshiness.

Part 4

ASSESSMENT OF CARCASS COMPOSITION

EEC Seminar on Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments, Zeist, 1975.

ANATOMICAL DISSECTION AND TISSUE SEPARATION : TECHNIQUES AND GROUPING OF TISSUES

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ABSTRACT

A copy of the document compiled by the Meat Research Institute on behalf of the European Association of Animal Production, Beef Carcasses, Methods of Dressing, Measuring, Jointing and Tissue Separation was made available to participants. This contains many examples of the diversity in methods employed in the assessment of carcass and meat characteristics.

Objectives in Anatomical Dissection are discussed and are deemed to be the determination or prediction of the following characteristics.

1. Weight of lean	4. Weight of SCF	7. Distribution of IMF
2. Distribution of lean	5. Distribution of SCF	8. Weight of KKCF
3. Thickness of lean	6. Weight of IMF	9. Weight of bone

Asymmetry in KKCF development can create problems in the presentation of results. This may be overcome by expressing composition in terms of side weight excluding KKCF, or alternatively by including the average of the weights of the left and right KKCF as a part of the weight of each side.

Anatomical jointing is difficult in well finished carcasses, but a very large number of the potential advantages of an anatomical approach to the development of effective prediction equations are lost, unless preliminary jointing is undertaken. An international standard method of anatomical jointing is suggested to overcome this problem.

Losses cannot be apportioned to single tissues and provided they are kept to a minimum (say 2% or less) they should be excluded from the side or carcass weight.

The various ways in which tissues are separated and grouped is indicated and dissection evidence is presented for including all tissues not readily associated with lean, fat or bone with IMF.

Introduction

It has been emphasised that one of the main purposes of this seminar is, following discussion, to reach conclusions and make recommendations concerning the achievement of more uniformity in the methods of assessment of carcass and meat characteristics at the end of beef production experiments. An essential pre-requisite to discussion is an appreciation of the diversity in methods which exists at present.

In 1972, the CATTLE COMMISSION of the EUROPEAN ASSOCIATION OF ANIMAL PRODUCTION decided to collect details of beef cutting and dissection techniques in member countries. A comprehensive questionnaire covering most of the events which might occur from the time of arrival of the live animal at the abattoir to the final calculations of carcass composition was sent to over 100 addresses. Institutes in 20 countries, Belgium, Czechoslovakia, Denmark, Finland, France, Germany, Greece, Hungary, Republic of Ireland, N. Ireland, Israel, Italy, Netherlands, Norway, Poland, Sweden, Switzerland, England, Scotland and Yugoslavia responded and a total of 42 verified replies to the questionnaire have been summarised in one provisional document (Pomeroy and Williams, 1975a).

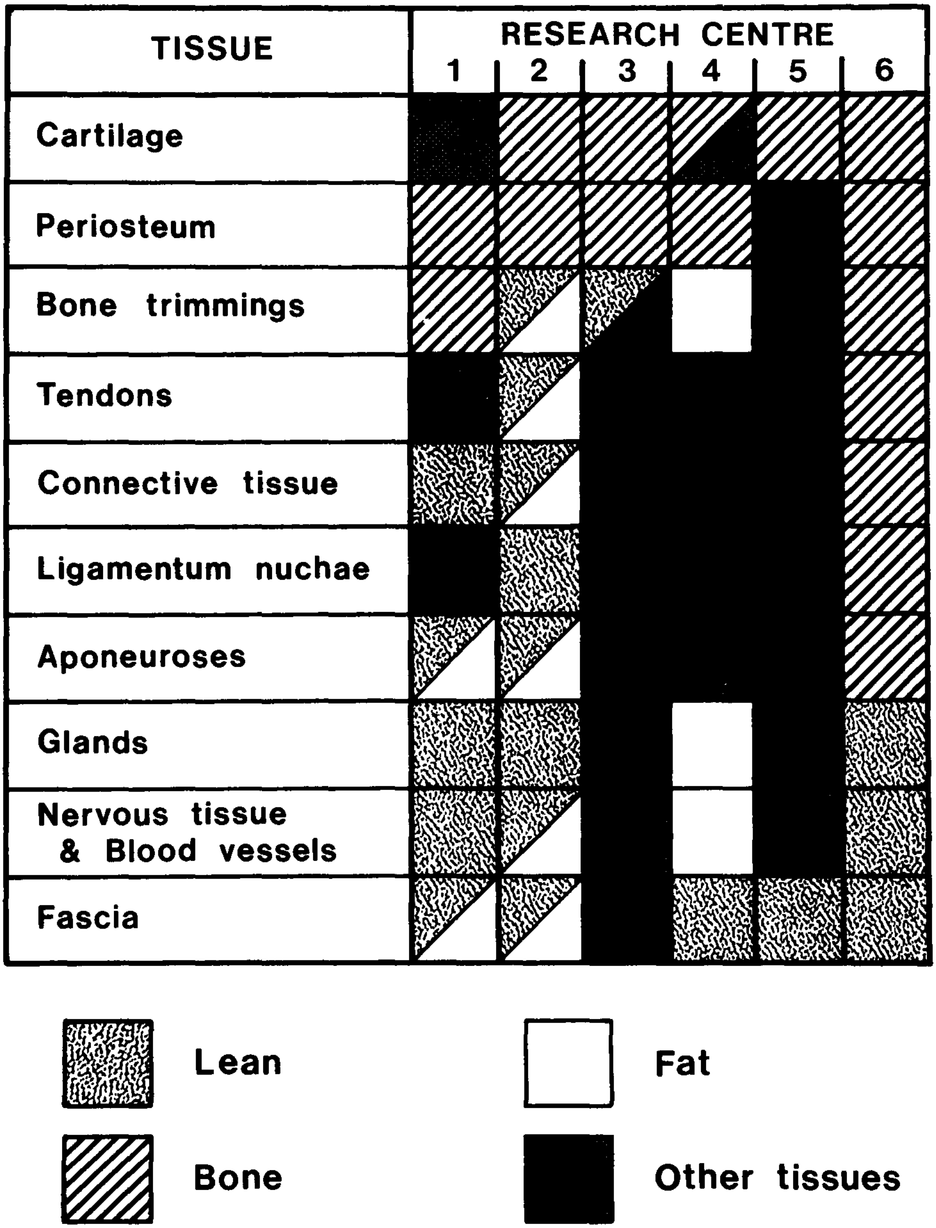
A copy of this document will be made available to every participant in the seminar. It contains many examples of the diversity in methods. For instance, 24 replies to the questionnaire yielded 7 different ways of measuring the length of the side! Four replies indicated that the length was measured in two different ways, but the most common method was from the 'tip' of the symphysis pubis to the anterior edge of the middle of the 1st rib. Differences of this kind would be particularly important if side length is used in prediction equations or if the relationship between the weight of dissected lean to skeletal dimensions is adopted as an index of muscle (lean) thickness.

In studies of carcass composition by dissection, a first necessity is to agree upon the definition, method of separation and grouping of the various tissues. The diversity which exists at present is shown in the EAAP provisional document (Pomeroy and Williams, 1975a). By way of illustration, Fig. 1 shows some of the different ways in which some tissues are 'allocated' to fat, lean or bone.

Objectives in Anatomical Dissection

The studies by Butterfield (1963), and others since 1963, have demonstrated that there is less variation than was hitherto supposed to exist in the anatomical distribution, by weight, of muscular tissue in commercial beef carcasses.

FIG. 1 **GROUPING OF TISSUES**



Such variation as does exist is mainly attributable to sex rather than breed or cross (though breed differences do exist), conformation or method of feeding. An anatomical approach offers the most precise method of examining this question and may reveal differences in distribution, which though smaller than hitherto supposed, are of sufficient magnitude to justify their serious consideration in breeding and/or feeding programmes. Harries, Williams and Pomeroy (1975) have shown that, in the British market, the main determinant of retail value is undoubtedly the percentage of lean in the side, but work in preparation (probably 1976) also shows that breed differences exist which cannot be explained solely in terms of the percentage of lean. Differences in distribution may be the explanation.

In addition to the lean content of carcasses, its thickness may be of importance, though we are not aware of evidence which conclusively demonstrates this.

Everitt, in 1966, concluded that meat animals need to be appraised on their yield of muscular tissue, or at least edible meat and that the yield of boneless fat-trimmed meat was rapidly becoming the criterion of commercial merit. However Carroll, also in 1966, considered that where evaluation is based on the yield of trimmed cuts etc .... the trimmed cuts could have a variable fat content which could introduce very serious errors. Consumer acceptance of fat differs from place to place and changes with time and it therefore seems likely that those studies which attempt to determine or predict the proportions or weights of lean, fat and bone will be more universal in application and of more permanent value than those which are directed towards the yield of edible meat according to a particular set of consumer preferences which may be transient.

Breed differences in the way in which fat is partitioned during growth of cattle into subcutaneous (SCF), intermuscular (IMF) and kidney knob and channel (KKCF) fat is an important source of variation in the characteristics of beef carcasses (Pomeroy and Williams, 1974), even though they may have the same overall composition. Unpublished data (Williams and Pomeroy, 1975) also suggest that the distribution of SCF and IMF among the different regions of the carcass is considerably more variable than that of muscular tissue.

In the light of the foregoing, it seems that the main objectives in anatomical studies of beef carcass composition by dissection should be the determination or prediction of the following characteristics.

1. Weight of lean
2. Distribution of lean
3. Thickness of lean
4. Weight of SCF
5. Distribution of SCF
6. Weight of IMF
7. Dkstribution of IMF
8. Weight of KKCF
9. Weight of bone

Anatomical jointing and dissection and definitions of major tissues

The method adopted at the Meat Research Institute is, very briefly, as follows:-

Kidney Knob and Channel Fat (KKCF)

This is removed from left and right sides and the weights are recorded. It includes all the internal fat surrounding the kidney and lying in the channel between the symphysis pubis and sacrum. Asymmetry in KKCF development is the biggest cause of side-to-side weight differences in any one carcass, but we have found that the bias is not consistently to either left or right sides. The mean difference between sides in KKCF weight for a few animals is quoted to illustrate this.

TABLE I - Mean difference in KKCF weight from left and right sides in some groups of cattle

Number of Carcasses	Breed	Asymmetry bias	Mean difference (kg)	Significance
14	S. Devons	L > R	0.401	P .01
15	Hereford	L > R	0.191	P .01
12	Charolais x Jersey	R > L	0.220	P .05
38	Friesians	R > L	0.337	P .01
26	Other Friesians	R > L	0.472	P .01

Because of the asymmetry, the weight of KKCF is not included in the side weight utilized in subsequent statistical analyses so that side-to-side and carcass to carcass differences in KKCF weight do not affect the comparisons. Nevertheless, the weight (or weight expressed as a percentage of side weight ex KKCF) of the KKCF is always quoted. An alternative solution to this difficulty would be to include the average of the weights of the left and right KKCF as a part of the weight of each side.

Quartering. Hanging sides are quartered posterior to the last rib, the cut being made with the knife held against the bone, but taken parallel to the hanging rail through the remaining soft tissues of the abdominal region.

Removal of subcutaneous fat (SCF). This is all the fat on the external surface of the side which can be removed without excavating into the grooves between muscles and also the fat which lies beneath *m. cutaneous trunci*. This includes the cod or udder fat. It is difficult to make an accurate anatomical identification of cod (or udder) fat, but it should be removed in a standardised manner and recorded separately. In practice, it is usually removed before quartering, on the hanging side.

The SCF is removed in regions which correspond to 8 joints, - Shin, Neck, Brisket and Crop in the forequarter and Sirloin, Flank, Round and leg in the hindquarter (see Pomeroy, Williams, Harries and Ryan, 1974). However, the demarcation between those regions which correspond to the dorsal and ventral joints is based upon 1½ times the "A" measurement of the eye muscle at the last rib, instead of between the 10th and 11th ribs. Removal of the SCF in this manner, - i.e. in regions which correspond to joints, - makes it possible to study variations between animals in the distribution of this fat.

Anatomical jointing

After removal of SCF anatomically defined forelimbs and hindlimbs are removed from the quarters. No major muscles are severed during this process. The forelimb includes the scapula, humerus, radius/ulna, and carpals and all the associated muscles. The hindlimb includes the sacral and caudal vertebrae, os coxae, femur, patella, tibia/fibula and tarsals and all associated muscles. A detailed listing of the muscles in each of the 'joints' would occupy too much space for this paper, but such lists, with a sample dissection record book can be supplied on request from the Meat Research Institute.

The sides after removal of SCF are thus separated into 4 anatomically defined joints:-

1. Neck and Thorax region 2. Forelimb	Forequarter
3. Lumbar and Abdominal region 4. Hindlimb	Hindquarter

The importance of jointing

The topic of this paper is anatomical dissection, tissue separation and grouping of tissues, - and this session of the seminar is heavily orientated towards sample joint techniques for the estimation of carcass composition. In this connection the anatomical dissection approach, as usually carried out at present, suffers from one very glaring weakness. This is that although the beef sides are normally quartered, no further anatomical jointing is usually undertaken before the quarters are dissected. Consequently, a very large number of the potential advantages of an anatomical approach to the development of effective prediction methods are lost.

A summary of the results, in terms of the residual standard deviations in kg, from the application of 4 possible methods of prediction to data derived from 72 sides of beef is presented in Table 2. The sides were dissected following a standardised commercial method of jointing, but this in no way invalidates the conclusions. The columns headed Y = FAT, show that side weight (X_1) alone

Table.2. The residual standard deviations (kg) in carcass component (Y) obtained by 4 different methods of prediction, where X_1 = side weight X_2 = weight of tissue in joint and X_3 = weight of joint. (NUMBER OF ANIMALS = 72)

Side weight alone 1. $Y = a + bX_1$	Y = BONE 1.77 kg			Y = LEAN 3.80 kg			Y = FAT 5.02 kg		
	2	3	4	2	3	4	2	3	4
Based upon	X_2	X_1 and X_2	X_1 X_2 and X_3	X_2	X_1 and X_2	X_1 X_2 and X_3	X_2	X_1 and X_2	X_1 X_2 and X_3
Leg + round + rump	0.51	0.43	0.42	2.30	1.90	1.35	2.20	2.19	1.51
Rump + round	0.58	0.54	0.53	2.42	2.02	1.44	2.16	2.12	1.54
Forerib + middlerib	0.98	0.97	0.81	4.68	3.01	1.49	1.96	1.85	1.53
Brisket	0.91	0.84	0.67	5.22	3.33	1.65	2.34	2.27	2.04
Foreloin	1.72	1.56	1.11	6.15	3.72	1.98	2.60	2.37	2.09
Shin	0.91	0.71	0.71	4.87	2.77	2.77	6.13	5.06	3.04

Note: 1. Lowest values underlined

yielded a residual standard deviation of 5.02 kg in method 1. Method 2, using tissue weights (X_2) alone, yielded lower RSD's in all joints except the shin. Method 3, using X_1 and X_2 in multiple regression yield lower RSD's than method 2. The important point is that methods 2 and 3 are the most commonly applied in attempts to develop prediction equations from anatomical data; certainly, they are the only ones we have seen published.

However, when the weight of the joint (X_3) is also included in the multiple regression (Method 4) there is a marked drop in all the residuals for the prediction of fat. A similar pattern is apparent when Y = BONE or LEAN, - the inclusion of the joint weight reduces the residual standard deviations for most joints, and very substantially so for some of them. (see Harrington & King, 1963, Hinks & Prescott, 1974).

In method 4, all three variables X_1, X_2 and X_3 are utilized in a multiple regression analysis, but they may also be used in a 5th way, - i.e. the direct estimation of the percentage tissues in the side from the percentages of tissues in the joints. The equation is then of the form:-

$$\frac{100Y}{X_1} = a + b\frac{100X_2}{X_3}$$

In Table 3 methods 4 and 5 are compared for 12 joints from the same 72 beef sides and it can be seen that method 4 is, in general, the more effective. The

Table 3 RSD (kg) from prediction equations (72 animals) X_1 = side weight, X_2 = weight of lean in joint, X_3 = weight of joint

Y = LEAN			Y = FAT			Y = BONE		
	MULTIPLE ABSOLUTE Method 4	SIMPLE * PERCENT Method 5		MULTIPLE ABSOLUTE Method 4	SIMPLE * PERCENT Method 5		MULTIPLE ABSOLUTE Method 4	SIMPLE * PERCENT Method 5
Shin	2.77	3.77	Shin	3.04	4.15	Leg	0.76	1.25
Leg	3.25	3.61	Leg	2.97	3.63	Shin	0.71	1.09
Middlerib	2.06	2.22	Steakpiece	2.19	2.81	Loin	1.10	1.35
Round	1.73	1.90	Round	2.01	2.31	Flank	1.35	1.49
Brisket	1.65	1.80	Middlerib	2.12	2.26	Neck	0.70	0.94
Loin	2.22	2.33	Rump	1.91	2.05	Middlerib	1.00	1.14
Flank	1.89	1.95	Neck	2.47	2.56	Round	0.62	0.77
Steakpiece	2.35	2.38	Flank	2.55	2.61	Rump	1.33	1.40
Neck	2.24	2.27	Brisket	2.04	2.07	Brisket	0.67	0.73
Foreloin	1.98	2.00	Foreloin	2.09	2.09	Steakpiece	1.35	1.36
Forerib	1.53	1.51	Forerib	1.61	1.56	Foreloin	1.11	1.11
Rump	2.11	2.02	Loin	2.23	2.14	Forerib	0.90	0.90

NOTE: * SD in kg after conversion of the percent deviation (method 5) for each animal into kg.

reduction in the residual variance attributable to the application of method 4 when compared with method 5 is substantial (between 2.3 to 14.3%) for 4 joints in the prediction of fat and 8 joints in the prediction of bone. Similar results have been confirmed in two other groups of 30 and 43 animals.

The conclusion from this must be that anatomical dissection should be preceded by anatomical jointing. The elimination or at least reduction in butchering error and side-to-side variation is then likely to give the anatomical approach a predictive advantage over any standardised commercial method of jointing and dissection.

A standard method of anatomical jointing is outlined in Fig. 2.

Figure 2 ANATOMICAL JOINTING - Suggested international standard method.

1. K.K. + C.F. 2. Cod/Udder fat

3. Quartering - Behind last rib

4. Subcutaneous Fat (SCF) - Regions 5. Defatted Quarters

Standardised Commercial		Anatomical	
Hindquarter	Forequarter	1. Neck and Thorax Region	Forequarter
Leg	Shin	2. Distal Forelimb	
Round	Neck	3. Proximal Forelimb	
Flank	Brisket	4. Lumbar Region	Hindquarter
Sirloin	Crop	5. Abdominal Region	
		6. Distal Hindlimb	
		7. Proximal Hindlimb	

This is in accord with the general view that the number of joints in any international acceptable standard method should be kept small. It would be a simple matter to divide the limbs, anatomically, into distal and proximal regions, and the lumbar and abdominal region into two anatomical units.

Tissue Separation

Muscle or lean is dissected as individual muscles, with tendons removed from muscles at right angles at the limit of the red lean and with connective tissue sheaths removed from the abdominal muscles.

Bone includes all cartilage, as at the dorsal edge of the scapula and costal cartilages, - cleaned of all traces of muscles, tendon and fat and scraped to remove periosteum. Individual bones are separated and cleaned independently. The removal of the periosteum was adopted as an 'insurance' policy, - to be certain that all bones were properly cleaned, but it is a time-consuming part of the trimming process and we may relax the standards in this connection.

Whenever possible, the bones of the axial skeleton (cervical, thoracic, lumbar, sacral vertebrae and sternum) are removed from the undissected side also. This permits a correction for splitting error to be made.

Intermuscular fat (IMF)

This covers all of the remaining tissues, including Other Tissues (OT) such as glands, nerves, blood vessels, tendons removed from muscles, connective tissue sheaths from the abdominal muscles, bone cleanings and any other connective tissues such as the ligamentum nuchae. Our reasons for including OT with IMF were given in Pomeroy, Williams, Harries and Ryan, 1974. In brief, they were that the chemical fat percentage in the OT was very different from that in the lean, but closely akin to that found in the dissectable fats and that the analysis of dissection data (see later) supported the view that OT should be included with IMF.

Losses and Grouping of Tissues

Losses. Every dissection also involves that awkward component, loss, - the difference in weight between the total of the dissected items and the original carcass or side weight. Losses cannot be properly apportioned to any single tissue and provided they are kept to a minimum (say 2% or less) the side or carcass weight should be accepted as the total weight of the dissected parts for calculating proportional composition etc. This seems a perfectly rational way in which to deal with this awkward carcass component, because such losses are in any event occasioned during normal commercial cutting and preparation for sale. The mean loss as a percentage of the original side-weight, together with its standard deviation, should of course be quoted.

Grouping of Tissues. Often, studies are concerned with establishing the lean, fat and bone composition of carcasses, - but all carcasses also contain Other Tissues (OT), material not readily identifiable as lean, fat or bone. In order to reduce the compositional scheme to one of three items only, which is necessary when we wish to consider sides of beef in terms of fat (SCF + IMF), lean and bone, the OT has to be ignored, or included with bone, or fat or lean. We have, as stated, chosen to include it with IMF and our reasons for so doing derive partly from a study of the dissection data (standardised butchery method) from both sides of 21 carcasses, the mean percentage composition of which is given in Table 4.

TABLE 4 - Mean Percentage Composition of 21 Carcasses

		SCF fat	IMF fat	B bone	L Lean	OT Tissues	Total	Total Tissues
HIND -	Round	8.7	6.3	10.1	69.6	5.3	100%	22.7
	Loin	10.6	10.6	11.0	61.4	6.4	"	7.4
	Rump	10.2	9.1	10.7	63.7	6.3	"	7.3
	Leg	7.8	2.6	30.5	46.1	13.0	"	4.9
	Flank	14.9	16.9	3.2	53.6	11.4	"	4.1
	Foreloin	14.7	15.5	13.6	49.3	6.9	"	3.5
FORE -	Brisket	9.8	20.0	12.1	48.9	9.2	100%	11.8
	Neck	7.9	11.3	17.0	55.0	8.8	"	11.0
	Middle rib	5.9	10.1	12.7	64.3	7.0	"	9.0
	Steakpiece	2.0	11.4	8.6	70.6	7.4	"	9.6
	Forerib	6.9	15.8	14.4	55.4	7.5	"	5.5
	Shin	4.2	1.7	34.3	46.4	13.4	"	3.2
SIDE		8.3	10.8	13.1	60.1	7.7	100%	100%

Table 4 shows that OT forms a substantial proportion of several joints and cannot be ignored. Although side to side differences in beef carcasses (other than the KKCF) have been reported, e.g. Brungardt, V.H. and Bray, R.W. (1963) and Van der Meij, G.J.W. (1973) they do not invalidate the following analysis for the 21 carcasses.

On the assumption that carcasses are symmetrical, perfect dissection would be represented by a zero standard deviation for the difference in weight between the tissues of the left and right sides of the carcasses. In practice, some interchange of material between some or all of the tissues is inevitable. In consequence, although the standard deviation would not be zero, the tissues which were dissected most consistently would be represented by a minimum standard deviation. The effect of including the weight of OT with each of the other constituents in turn is summarized in Table 5.

Including OT with lean or bone or SCF substantially increased the standard deviation. Including OT with IMF substantially decreased the standard deviation. It was therefore concluded that the portion of the recorded OT other than glands, nerves, blood vessels, etc., was derived mainly from IMF, and that the interchange of material during dissection was greatest between IMF and OT.

TABLE 5 - Mean Composition and Differences Left-Right Sides

21 Carcasses

Item	Percent Composition	SD (Left-Right) (g)	
Other tissues (OT)	7.7	453	
		Alone	with OT
Lean	60.1	756	1003
Bone	13.1	473	687
SCF	8.3	324	521
IMF	10.8	509	328
TOTAL	100%		

Thus, including OT with IMF is more consistent with the hypothesis that a beef carcass is symmetrical, and the item OT is included with IMF whenever composition is considered in terms of the three main tissues, fat, lean and bone, which by summation, equals the side weight.

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Wholesale and retail jointing
Techniques and standardisation for experimental purposes

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Abstract

A standardised cutting method for carcasses and cuts is only obtainable when it is anatomically based. A modification of the DLG-Cutting-System (German Agriculture Society), which is defined anatomically and which guarantees both repeatability and flexibility, is recommended, particularly so because the removal and division of the ventral cuts may form a basis for further separation of carcasses. The dissection of the round and shoulder into retail cuts should be carried out by following the natural major muscle seams.

The development of muscle and fat depends upon specific conformities in the pattern of growth in the different regions of the carcass. The correlations between cuts resulting from these growth patterns allows for, within biological limits, a predictability in slaughter criteria for various purposes. On the basis of standardised cutting methods it is suggested that:

- cuts are a basic reference for the characterisation of carcasses
- or carcasses, specifically the results of carcass assessment, give information about the cuts and their composition.

When considered in terms of the amount of information contained, and the cost and time involved, the proportion of kidney and pelvic fat may be an important objective reference value for the composition of the carcass and its cuts. We have also found a close correlation between the composition of the primal rib and the composition of the whole carcass, as well as between the flank and carcass.

Introduction

The set theme is very complex since aspects of the market economy as well as of experimental method have to be considered. The standardisation of cutting methods of carcasses and cuts is only possible when they can be defined anatomically.

The development of muscle and fat depends upon specific conformities in the pattern of growth in the different regions of the carcass. The correlations between cuts resulting from these growth patterns allows for, within biological limits, a predictability in slaughter criteria for various purposes. A prerequisite for all purposes is, however, a standardised cutting method.

On the basis of standardised cutting methods it is suggested that:

- cuts are a basic reference for the characterisation of carcasses or
- carcasses, specifically the results of carcass assessment, give information about the cuts and their composition.

Cutting methods of carcasses and cuts for experimental purposes

A repeatable cutting method must be guaranteed. As long as the cutting method is done by the same person, there are hardly any variations to be expected. However, there is a degree of variation among different institutions even when the same cutting method is used. The necessary basis for any supraregional comparison of the results is a clear definition of the cutting method of carcasses.

What are the main points involved?

- Preparation of the carcass
- Definition of the cutting method for cuts

The "DLG-System" (DLG = German Agriculture Society) will be used as a basis for discussion (Fig. 1). It uses, with few exceptions, anatomically clear bounds. Furthermore this cutting method allows of the study of variation in quality resulting from the variable deposition of muscle and fat on the carcass.

There is some degree of variation produced when the loin, primal rib and fore rib are cut and also when the brisket and flat rib are separated. Differences affecting dissection results may start with the dressing of the carcass. The separation of head, feet, tail, diaphragm or kidney and pelvic fat is practised in different ways. For experimental purposes only the head and feet should be cut off from the carcass.

Definition of the bovine carcass:

The whole body of a slaughtered animal split lengthwise in the approximate medial line of the vertebral column, after bleeding, skinning and evisceration, and removal of head, feet, genitals of males and udders of female animals that have calved. The head is separated between carpus and metacarpus, and the hindfeet between tarsus and metatarsus. The spinal cord is removed.

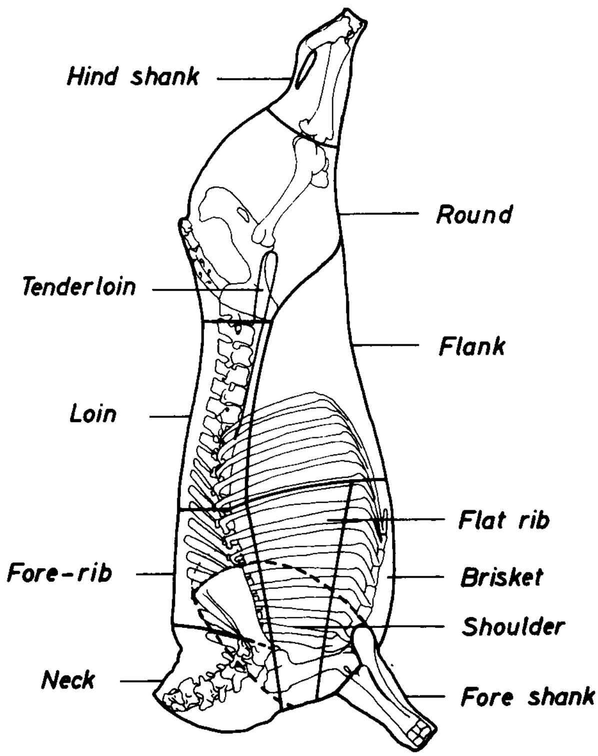


Fig. 1:

Cutting Method of the DLG-System

Usually the carcass side is quartered between the 8th and 9th thoracic rib. While the ventral cutting method in the hindquarter is anatomically defined, it is difficult to locate the exact points for the ventral bounds of cuts like fore rib and neck in the forequarter. Furthermore, it is usual to divide the forequarter from the hindquarter or pistola, respectively, between the 4th and 5th thoracic rib. A preliminary draft for some changes to the systems of dissection in use needs to be discussed. The reasons for this lie in the need for improved anatomical definition in cutting methods and the need for greater conformity in practice (Fig. 2).

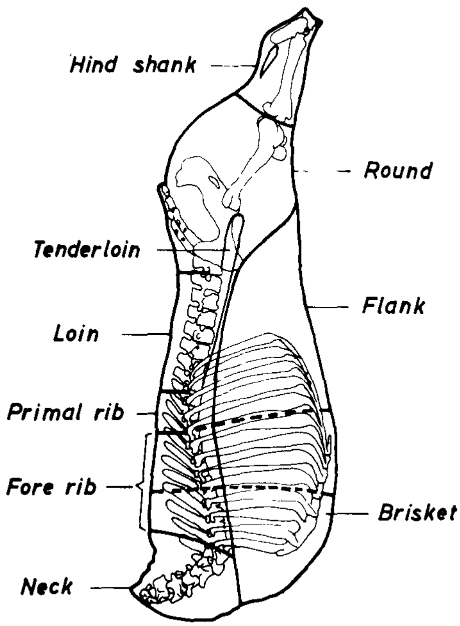


Fig. 2:

Cutting Method (DLG-System) with some modifications

Procedure for the modified cutting method by removal of

1. Kidneys
2. Kidney and pelvic fat from both sides of the warm carcass (weight divided by 2)
3. Shoulder with shank
   Laterally adherent part of the carcass, separated by the natural seam.

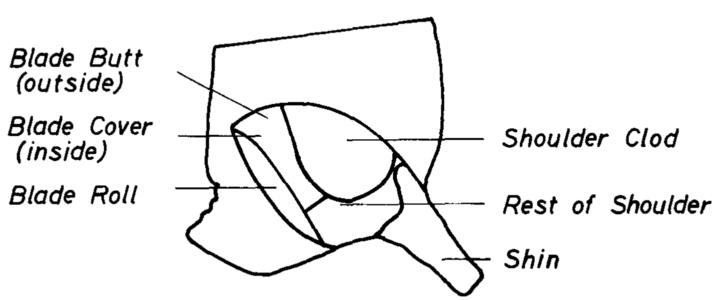


Fig. 3:

Shoulder, process for retail cuts, by separation of

3.1. Foreshank, at the elbow joint and inclusive of the tip of the elbow

3.2. Shoulder Clod
3.3. Blade Roll
3.4. Blade Butt — Bones are taken off (3.2.–3.6.)
3.5. Blade Cover
3.6. Rest of Shoulder

4. Entire ventral portion of the carcass

   The incision starts ventral the aitch bone (os coxae), from medial (inside) surface of the carcass, at the level of the pubic bone (os pubis) and through the junction of the M. tensor fasciae latae and the aponeurosis of M. obliquus externus abdominis. It runs cranially without removing any of the leg muscles to the most anterior point of the iliac bone (os ilium), the tuber coxae (cut changes on this point to the outside of the carcass for more precision), proceeding parallel to the dorsal surface up to the cranial end of the carcass.

5. Cuts of the back at right angles to the vertebral column

   5.1. between 7th cervival vertebra and 1st thoracic vertebra (Neck)

   5.2. between 4th and 5th thoracic vertebrae (cranial part of the fore rib, the rest included in the pistola)

   5.3. between 8th and 9th thoracic vertebrae (caudal part of the fore rib)

   5.4. between 11th and 12th thoracic vertebrae (primal rib)

   5.5. between the last lumbar vertebra and the first sacral vertebra (loin, the rest included the round)

6. Tenderloin, removed following the natural muscle seam

7. Round (Fig. 4)

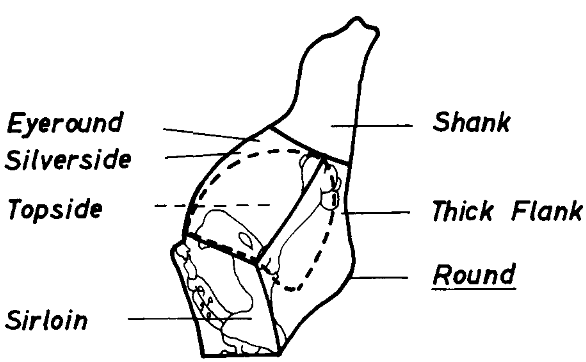


Fig. 4:

Round, dissected into retail cuts by following the natural muscle seams

7.1. Hind shank, removed from the round by a concave cut through the knee joint

7.2. Sirloin
7.3. Thick Flank or Knuckle
7.4. Silverside, eventually Eyeround
7.5. Topside
} Bones are taken off

8. Ventral part of the carcass, by a cut along the ribs
   8.1. between 4th and 5th thoracic ribs (tip of the brisket)
   8.2. between 8th and 9th ribs (brisket)
   8.3. eventually after the last rib, by a round cut (boneless flank)

This discussed cutting method is very detailed. However, it is flexible and it is possible to make bigger units by putting them together arithmetically or by less division during preparation.

Variable cutting method for the trade

Economical considerations resulted in an extension of the national and international trade in carcasses and cuts. The demands of the buyers are regionally and seasonally different with regard to the cutting methodology. To this end also, standardisation is advantageous. It makes it possible to use modern methods of communication and is at the same time a guarantee for the buyer. Variation of the cutting method in the trade, starting as it does with the dressing of the carcass, contrasts with that employed in experimental work. A uniform definition, as well as a flexible description of cuts is indispensable to the special needs of both the national and international trades.

Assessment of conformation and fatty tissue as a reference value for carcasses and cuts

By means of correlation and regression coefficients it was proved that an adequate and comparable carcass evaluation is a

> basis for the composition of the carcass (Percentage of muscle, fat and bone), and of its cuts,

because the growth of fatty tissue, muscle and bone is specific in the cuts of carcasses. By additional identification of the fatness within the conformation score, a more precise subdivision not only of muscle, fatty tissue and bone content of the whole carcass is effected, but the cuts are, according to their growth development, appraised more accurately. In a similar way cuts can also be used to appraise carcasses. Of special importance are pistolas (Table 1).

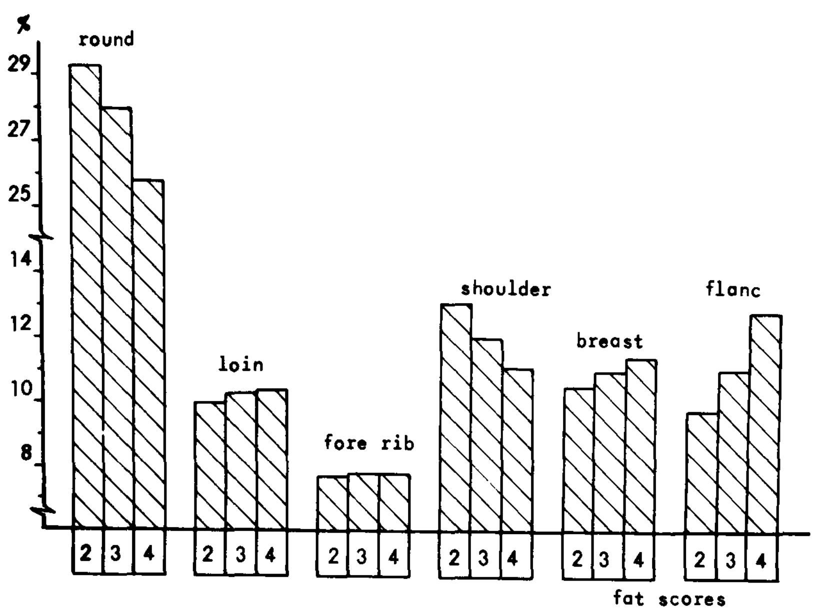
Table 1: Pistolas from Heifers - conformation score [4] fat scores [2|3|4]-, their portion in % of carcass and their tissue composition.

Fat score	Pistola as % of carcass	Tissue as % of Pistola			
		muscle	fat tissue	bone	tendons
	$\bar{x}$ %	$\bar{x}$ %	$\bar{x}$ %	$\bar{x}$ %	$\bar{x}$ %
2	45,0	74,0	4,2	18,6	3,2
3	42,9	71,6	8,3	17,0	3,1
4	40,2	67,8	13,3	15,9	3,0

The calculation was done on the basis of 5 scores for the conformation and fat (5 = score for the maximum, 1 = score for the minimum).

In Fig. 5 differences in the proportions of the cuts are shown. While the proportion of the round and shoulder decrease with increasing fatness, breast and flank obviously increase. The changes in loin and forerib are negligible.

Fig. 5: Changing proportions of the cuts - conformation [4] fat scores [2|3|4]



There are relatively close correlations between the proportion of fat in the carcass and the proportion of fat in the cuts (Table 2).

Table 2: Correlation coefficients from the relationships between total carcass fat (subcutaneous + intermuscular + kidney and pelvic) as % of carcass weight and total fat (subcutaneous + intermuscular) in the cuts, as % of cut weight.

Total fatty tissue as % of carcasses :	Young bulls r	b%	Heifers r	b%
Fat tissue % of Hind shank	+0,662	0,41	+0,275	0,21
" " Round	+0,863	0,57	+0,917	0,55
" " Loin	+0,863	0,87	+0,914	0,86
" " Primal rib	+0,896	0,96	+0,810	0,95
" " Fore rib	+0,898	0,96	+0,880	0,80
" " Neck	+0,720	0,80	+0,680	0,64
" " Shoulder	+0,886	0,69	+0,863	1,26
" " Brisket	+0,935	1,56	+0,903	1,51
" " Flat rib	+0,940	1,74	+0,925	1,67
" " Bone flank	+0,964	1,98	+0,830	2,08
" " Meat flank	+0,977	1,78	+0,838	1,94
" " Fore shank	+0,662	0,41	+0,275	0,22
" " Kidney/Pelvic fat	+0,899	0,28	+0,858	0,22

Table 2 shows an increasing fat content in the cuts under the influence of the total fat content of the carcass. In contrast to this is the decrease in the muscle content. There is striking difference between round and flank.

When considered in terms of amount of information contained, and the cost and time involved, the proportion of kidney and pelvic fat may be an important objective reference value for the composition of the carcass and its cuts.

The basis for a subjective assessment of the carcasses or an objective reference value is a comparable judgment and an anatomically fixed, standardised cutting method.

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SAMPLE JOINT DISSECTION AS A MEASURE OF CARCASS COMPOSITION

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Abstract

In the present paper the use of rib joints as predictors of carcass composition has been discussed. The influences of environmental conditions, breed and type within breeds have been mentioned as limiting factors of sample joint methods. Studies on the basis of the muscle distribution have indicated the shoulder as a carcass part with special merits for the prediction of the carcass composition.

Introduction

The carcass composition is an important aspect of the slaughter value of an animal. Jointing or dissection of a carcass gives the best impression of the composition but the financial losses are high and the methods are very laborious. Simplified methods to predict the carcass composition therefore are of great interest, provided that they give reliable results.

One of the simplified methods to predict carcass composition is the dissection of sample joints. Such sample joints can be wholesale joints, parts of the carcass defined by the location of skeletal reference points (rib joints, shins) or individual muscles and bones. The sample joints are mostly dissected by complete tissue separation or analyzed chemically.

Methods and results from literature

As a rule beef carcasses are divided into fore and hind quarters by cuts along one of the ribs. Rib joints, which are adjacent to the line of quartering through the carcass and comprising one or more ribs, have often been taken as sample joints, because of their ease of removal in the slaughter house. Various rib joints have been used, e.g. 13th rib (Mason, 1951), 12th rib (Crown et al., 1960), the frequently used 9-11th rib (Hankins et al., 1946) and the 7-9th rib (Martin et al., 1962). Robelin et al. (1975) described the dissection of the 11th rib to predict chemical carcass composition. In the dorso-ventral direction the rib joint can equal the total carcass depth as in the work of Martin et al. (1962)

using the 7-9th ribs; alternatively only the dorsal part may be dissected as in the case of Hankins et al. (1946), using the 9-11th ribs.

Individual muscles or muscle combinations also have been mentioned as predictors of carcass composition (Orme et al., 1960; Butterfield, 1962). Data from the Anglo-Saxon countries originate mostly from steers and heifers of the British beef breeds, whereas most of the experiments on the West-European continent were done with young bulls of the local breeds. The carcasses of the latter animals are in general leaner as a result of sex and breed and this may have influenced the results of the sample joint methods.

Comparisons between data of sample joint dissections and carcass composition have been made on quite different bases in the studies. The sample joint composition has been compared with standardized wholesale jointings, anatomical dissections with complete tissue separation and chemical carcass analysis. In most of the studies sample joints have been dissected by complete tissue separation and this means that only on the basis of complete tissue separation of the carcass can comparisons be made based on identical methods for both sample joint and carcass. In other methods insufficient accuracy of the method can originate from the sample joint as well as from the dissection technique of the carcass.

The relationship between the composition of sample joints and carcasses in terms of percentages of the tissues is in most of the studies good or very good. As far as standard errors of the estimate have been mentioned these are below 3.6 %. The relation of the bone fraction is, at least in rib joint methods, poorer than that of muscle and fat fractions. There is little doubt that inaccuracies of splitting the carcasses into sides have an important direct influence on the bone fraction.

The animal material used for the several studies varied considerably with regard to sex, breed, age, carcass weight and carcass composition. Therefore it is extremely difficult to draw conclusions about the universal application of sample joint techniques for prediction of the carcass composition. Some of the methods, especially rib joint dissections, can be considered as useful methods to predict the carcass composition in small groups of animals with reasonable differences in carcass composition. The variation involved is too great to predict the carcass composition in individuals with sufficient accuracy. Whether sample joints can be used to replace carcass dissection depends on the type of experiment and the precision required.

There can be several reasons for the lack of accuracy of sample joint methods. In some of our own studies rib joint dissections were included to get an idea of the reliability of the methods and the sources of variation, with the aim to improve the methods if possible.

Own research on rib joints as predictors of carcass composition

In some experiments with beef animals rib joint dissection data have been compared with carcass dissection data. The rib joint 9-11 was dissected in a study using 43 Dutch Red and White and 53 Dutch Friesian intensively fed young bulls, slaughtered at 425 kg standard live weight. The carcass sides in this study were dissected by a standardized wholesale jointing method with excess fat trimmed from the joints. In another study the rib joint 7-9 was compared with an anatomical dissection with complete separation of muscles and dissectible fat. The material for this study comprised 25 young bulls and 25 heifers intensively fed to 425 and 375 kg liveweight respectively and 25 steers and 25 heifers intensively fed until 2-2½ years. In a group of 13 young bulls the merits of the individual rib joints from the 5th-13th rib as predictors of the carcass composition have been studied.

The rib joint 9-11

The boundaries of this rib joint are as indicated by Hankins et al. (1946) and illustrated in fig. 1. An incomplete separation between muscles and fat in the side means that in the fatter animals more of the intermuscular fat has been counted as "lean" than was the case in the leaner ones. This reduces the variation in the lean/fat ratio in the carcass. The average muscle percentage in the rib joint was 65.7 ± 3.2 and the average lean percentage in the carcass sides 71.2 ± 1.9. In table 1 some data are given per breed because of the existence of significant breed differences. The better muscles and later maturing Dutch Red and White animals are in general leaner and therefore it could be expected that the breed influences were associated with the differences in fatness. This proved to be true, but if the muscle to fat ratio in the rib joint was included to explain the lean percentage in the side, highly significant breed influences existed. This finding is difficult to explain but there is some evidence that the fat partitioning between the main fat depots has played a role. The correlation coefficients for the percentages

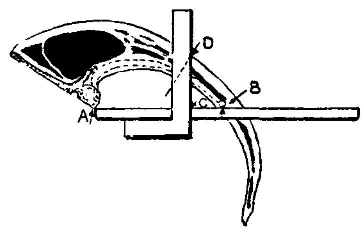

Figure 1. Ventral boundary of the rib joint 9-11.
AC = 61½ % of AB

Table 1. Relationships between composition factors of the rib joint 9-11 (RJ) and carcass side following a standardized wholesale jointing with fat trim (CS).
Data from 43 Dutch Red and White and 53 Dutch Friesian young bulls, intensively fed until 425 kg liveweight.

Relation-ships studied	Breed	$\bar{x}$ (RJ)	$\bar{y}$ (CS)	Regr. coeff.	St.dev. regr. c.	Correl. coeff.	St.error estimate	Test for different regression	Test for different intercept
Muscle%/lean%	DRW	67.4	72.6	0.391	0.062	0.699	1.136	*	***
	DFr	64.4	70.2	0.226	1.366	0.445	1.365		
Fat%	DRW	15.2	8.6	0.550	0.057	0.831	0.929		*
	DFr	18.3	10.7	0.442	0.046	0.800	0.983		
Bone%	DRW	16.0	15.2	0.216	0.068	0.439	0.764		***
	DFr	15.9	15.8	0.360	0.012	0.426	1.251		
Muscle/lean wt	DRW	2.1	90.4	13.973	2.517	0.655	3.446	*	***
	DFr	2.1	85.2	7.992	2.073	0.475	2.998		
Fat weight	DRW	0.5	10.8	17.059	2.184	0.773	1.359		*
	DFr	0.6	13.0	15.496	1.824	0.765	1.328		
Bone weight	DRW	0.5	18.9	1.945	1.876	0.160	0.870	*	
	DFr	0.5	19.1	9.814	4.586	0.287	1.661		

Weights in kg

are rather low if compared with data from literature for the same rib joint. The correlation coefficients for absolute tissue weights are lower than those for the percentages but this is a common aspect of all data from similar studies.

Table 2. Relationships between composition factors of the rib joint 7-9 (RJ) and carcass side following an anatomical dissection with complete separation between muscles and dissectible fat (CS).
Data from 25 intensively fed young bulls (425 kg live wt), 25 intensively fed heifers (375 kg live wt), 25 steers extensively fed (2½ yrs) and 25 extensively fed heifers (2 yrs). Each group consisted of Dutch Red and White, Dutch Friesian, D.R.W.xD.Fr., Charolais x D.Fr. and Limousin x D.Fr. animals in equal numbers.

Relationships studied	Sex and weight or age	$\bar{x}$ (RJ)	$\bar{y}$ (CS)	Regr. coeff.	St.dev. regr.c.	Correl. coeff.	St.error estimate
Muscle%	♂ 425 kg	61.3	65.9	0.770	0.041	0.969	0.845
	⚲ 2½ yrs	55.3	60.5	0.679	0.056	0.930	1.087
	♀ 375 kg	55.6	61.5	0.775	0.071	0.916	1.399
	♀ 2 yrs	56.3	61.8	0.810	0.079	0.905	1.493
Fat%	♂ 425 kg	21.4	15.2	0.772	0.058	0.940	1.156
	⚲ 2½ yrs	26.7	19.1	0.733	0.060	0.932	1.154
	♀ 375 kg	29.1	20.9	0.763	0.072	0.911	1.401
	♀ 2 yrs	26.0	17.9	0.755	0.061	0.933	1.288
Bone%	♂ 425 kg	16.8	15.0	0.546	0.163	0.573	0.705
	⚲ 2½ yrs	17.6	15.4	0.450	0.082	0.752	0.551
	♀ 375 kg	14.7	13.9	0.504	0.095	0.743	0.580
	♀ 2 yrs	17.3	15.5	0.607	0.086	0.826	0.724
Muscle wt	♂ 425 kg	5.3	80.0	9.154	1.051	0.876	2.965
	⚲ 2½ yrs	5.7	91.6	11.229	1.231	0.885	3.400
	♀ 375 kg	4.2	62.9	11.706	1.221	0.894	2.440
	♀ 2 yrs	4.6	70.8	7.858	1.214	0.803	3.014
Fat wt	♂ 425 kg	1.8	18.3	10.244	1.102	0.889	1.752
	⚲ 2½ yrs	2.8	28.8	8.826	0.788	0.919	1.813
	♀ 375 kg	2.2	21.2	8.624	1.180	0.836	1.681
	♀ 2 yrs	2.1	20.5	10.744	0.789	0.943	1.372
Bone wt	♂ 425 kg	1.5	18.2	3.564	1.864	0.378	0.736
	⚲ 2½ yrs	1.8	23.2	7.479	1.632	0.691	1.155
	♀ 375 kg	1.1	14.2	4.832	1.369	0.593	0.600
	♀ 2 yrs	1.4	17.7	6.267	1.517	0.653	0.953

Weights in kg

The rib joint 7-9

The procedure is as indicated by Martin et al. (1966). The rib joints were taken from the side which was then anatomically dissected. This made it necessary to weigh the parts of the individual muscles in the sample joint. These muscle portions, expressed as percentages of the entire muscles, can give an idea of the precision of removal of the rib joint from the side. Even if removed with great care there existed a very large variation in the weights of the muscle parts relative to the total weights of the individual muscles. If the rib joint gives rather good results this apparently depends more on the size of the joint than on the jointing lines. In fig. 2 the position of the components within the rib joint is illustrated. It is clear that small deviations of the cutting lines can have an important influence. Some data are given in table 2. Per group all animals have been fed under the same standard conditions. The relationship between the composition of the rib joint and the carcass was in general good with rather low standard errors of the estimate. When in the group of young bulls data from some Jersey bulls of much lower carcass weight but fed under the same standard feeding conditions were included the situation changed only slightly. If, however, the material was extended to include 17 young bulls fed under different conditions the standard error of the estimate increased considerably. On the other hand the differences for both groups of heifers were small and not significant.

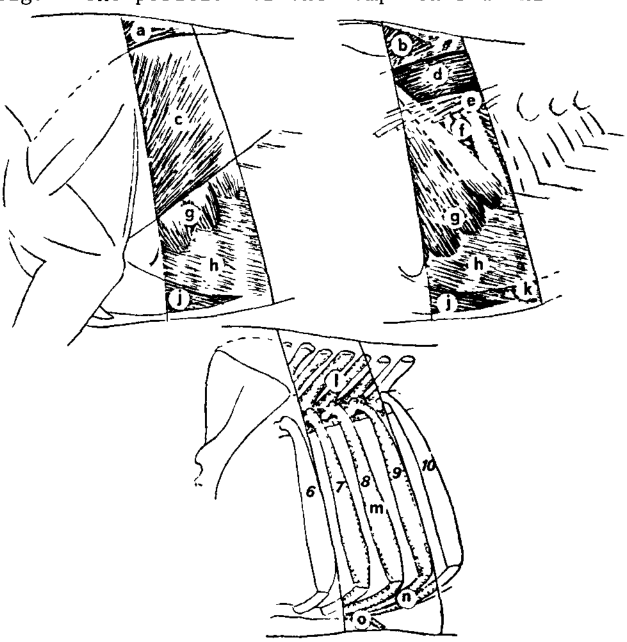

Figure 2. The position of the components within the rib joint 7-9. (These components have not been further specified.)

Rib joint 7-9 dissections have been used in a study with 66 young bulls of the Dutch breed and slaughtered at 425 kg liveweight. In this study no carcasses were dissected. The animals were fed under different conditions. From the tissue weights in the rib joint the carcass weight was calculated. The common offal percentages and losses at dissection which are always very constant were taken into account. Deviations from the recorded carcass weight (cold carcass wt = 100 %) for animals from 4 progeny groups are given in table 3. There proved to be systematic influences of the feeding system, breed and types within breeds on the deviations. The regression equations were calculated using data from young bulls fed in an identical way to the group in table 3 which were restricted according to their weights.

Table 3. Deviations between the carcass weight calculated from the tissue weights in the rib joint 7-9 and the recorded cold carcass weight.

Feeding system		Ad libitum		Restricted according to weight		Restricted according to age	
Progeny group / breed		mean	st.dev.	mean	st.dev.	mean	st.dev.
B	DFr	109.7	3.7	107.1	4.6	103.1	3.8
H.K.	DFr	103.3	3.0	102.6	2.3	100.1	0.7
M.O.	DRW	102.2	2.8	96.7	0.7	96.4	2.3
D.B.	DRW	102.6	5.2	97.0	1.8	98.9	3.6

The recorded cold carcass weight is taken as 100 % and the regressions have been calculated on animals fed under the same conditions as the restricted according to weight group.

Results of rib joints comprising individual ribs 5-13

In a small number of carcasses (13 young bulls of the Dutch breeds) the results of dissection of joints comprising individual ribs from the 5th-13th were compared with anatomical carcass dissections. The rib joints were not taken from the dissected side. The boundaries of the part of the carcass for this study are illustrated in fig. 3. The part A1-A2-B1-C3-A3-A4 was the one considered. The 5th rib is the first rib free from the shoulder musculature and caudal to the 10th rib the ventral edge of the rib cartilages was taken as the

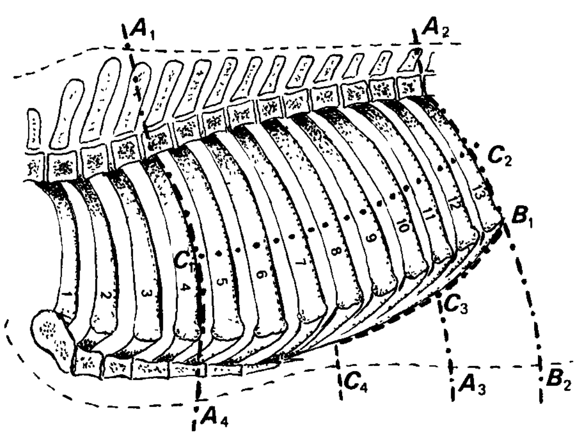

Figure 3. Part of carcass used in the study of rib joints comprising individual ribs 5-13.

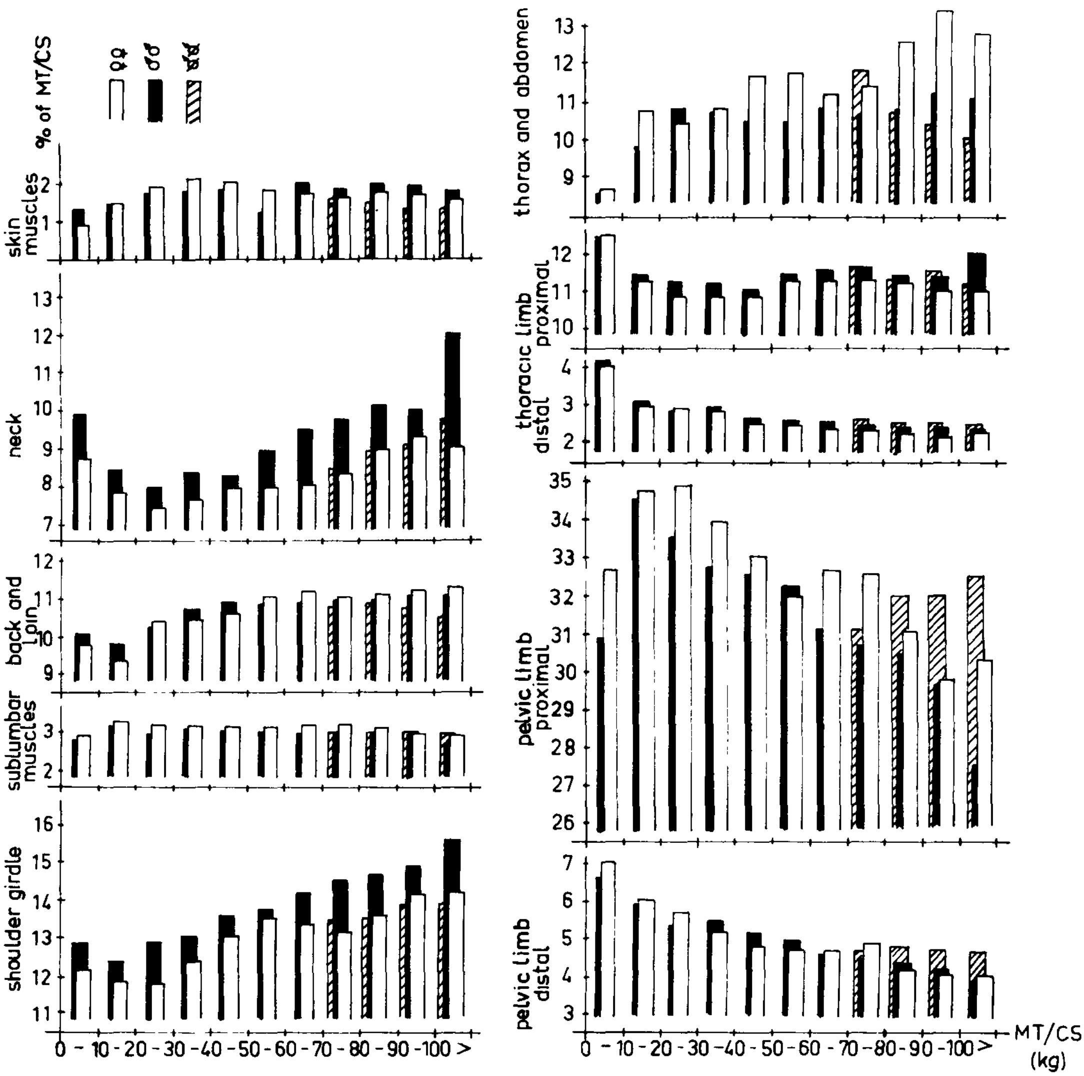

Fig. 4. Changes in the proportions of standard muscle groups, expressed as percentages of total muscle in the side, in relation to variation in total muscle, (MT/CS = 100 %).

most ventral point defining the boundary. Each rib joint was subdivided into a dorsal and ventral part at 50 % of the length of the visible part of the rib along C1-C2. The correlation coefficient for the muscle and fat percentage between rib joint and carcass side was for each individual rib joint higher for the total depth than for the dorsal part only. This did not confirm the findings of Kempster et al. (1974) that the rib region has special merits for prediction of the carcass composition although this could be expected also from the data of Butterfield (1963), Berg et al. (1974) and Bergström (1974a-b) since the relative growth of the muscles surrounding the spinal column is similar to the growth of the total musculature. In this study the size effect proved to be rather strong. The correlation coefficients for fat and muscle percentage increased from the 5th to the 8th rib, but decreased rather abruptly from the 9th to the 13th rib. The dorsal part of the rib joint 9-11 gave rather poor results (for muscle % r=0.604), but the correlation coefficients for muscle and fat percentage in the rib joint 7-9 were high (resp. r=0.934 and r=0.985). The best combination of three ribs was the rib joint 6-8 but the results of this combination and of the total rib joint 5-13 were only slightly better than those for the rib joint 7-9.

Individual muscles and bones as predictors of the carcass composition

Most of the sample joints in use for the prediction of the carcass composition have been developed in connection with jointing methods in practice. Two of the most important factors affecting the precision of sample joint methods are the degree of precision involved in removing the "joint" and the growth of the tissues in the parts relative to the growth of the tissues in the whole. The aspect of fat distribution within the total dissectible fat or within the important fat depots of subcutaneous fat, intermuscular fat and perinephric and pelvic fat can be an important factor too, but data are very scarce.
Several investigators have demonstrated that the relative growth of the components of the structural tissues in the carcass follows strict rules. Important changes in the muscle distribution only take place in relation to age or weight. If compared within narrow (physiological) age or weight ranges the influences of breed or type within breed proved to be very small in almost all experiments, (Butterfield, 1963; Berg et al., 1974; Mukhoty et al., 1973; Bergström, 1974a-b). Butterfield et al. (1967) did not find that growth rate influenced the muscle distribution if comparisons were made on the basis of equal total muscle weight. Refsgaard Andersen (1974) did not confirm this finding but the influence of

different feeding levels on the muscle distribution in his experiments were small. This means that some individual muscles and bones can be expected to be good predictors of the muscle and bone weight in the carcass by means of simple calculations. In fig. 4 the weights of muscles combined into standard muscle groups have been expressed as percentages of the total side muscle weight = 100 %. They are plotted against the absolute side muscle weight for a very heterogeneous material with regard to sex, breed or crossing, age or weight and environmental conditions. The female and male animals cover the total age range from birth to maturity. The weight range for the steers is narrower. It is evident from this figure that the changes in the percentages stand in rather close relation to the muscle weight. The same figures can be drawn for the individual muscles and these muscles follow rather frequently the sequence of the standard muscle group (functional unit) to which they belong. The most promising muscles or bones in this respect are those which have the lowest variation in the multiplication factor which equates their weights with total muscle or bone in the carcass side, over a wide weight or age range.

In table 4 the individual muscles and bones with a variation coefficient below 10 % are listed.

Table 4. Individual muscle and bones with a variation coefficient of the multiplication factor (relating their weights to total muscle and total bone in the side respectively) less than 10 %,for the total age range from birth to maturity and for all sexes.

Muscles:

musc. longissimus dorsi
multifidus dorsi
sublumbar muscle combination
musc. infraspinatus
supraspinatus
triceps brachii
biceps brachii
flexor and extensor muscles of fore shin
musc. gluteo-biceps femoris
glutaeus medius
semitendinosus
semimembranosus
quadriceps femoris
tensor fasciae latae
gracilis
flexor and extensor muscles of hind shin

Bones:

pelvis
total of ribs
scapula
humerus
femur
tibia / fibula combination
patella

Most of the muscles in table 4 are large muscles or very good anatomically defined muscles. Many of these same muscles have been indicated by Orme et al. (1960) for the same purpose. Within the narrow weight range for the steers a large proportion of the total number of muscles had variation coefficients below 10 % and a quarter was below 5 %. The group of shin muscles was a good predictor for the total muscle weight in the study of Butterfield (1962) but Kempster et al. (1974) found this muscle group not to be of such importance in this respect. Table 4 indicates that both shin muscle groups change appreciably over wider weight ranges. It is impractical to incorporate the muscles in table 4 in sample joints because of their size, commercial value or their location deep in the carcass. Of special interest is the shoulder with a muscle group, 4 individual muscles and 2 bones with a low variation coefficient. A disadvantage, however, is the size of this joint (14 % of the side weight).

Discussion

Data from sample joint dissections indicate that these simplified methods can be useful for the prediction of the carcass composition in small groups of animals with reasonable differences in composition. The variation involved is too large to give a sufficient precision for individual animals. The results mentioned in the literature vary and it may be expected that the nature of the material used for the several studies, especially with regard to the average level of fatness and range of fatness has had a rather important influence on the results. There are different reasons explaining the insufficient accuracy of the methods as predictors of carcass composition. In the first place studies with the rib joint 7-9 demonstrated clearly that the anatomical boundaries of the joint are very inaccurate. This can hardly be due to the technicalities of removal alone. Furthermore there is evidence for the existence of breed influences on the results of sample joint methods but also, and of a more serious nature, is the existence of influences of type within breeds and environmental conditions.

It is necessary that more dissection data be accumulated from both joints and carcass sides, especially concerning the fat distribution. The rib joint 7-9 over the total carcass depth gave better results than the rib joint 9-11 involving only the dorsal part of the carcass. Although the rib region has special merits for the prediction of the carss composition because the relative growth of the muscles surrounding the spinal column is similar to the growth of the total muscle weight, the size effect of the sample joint cannot be neglected.

Inaccurate delimiting of rib joints makes it unlikely that the muscle parts in the joint follow closely the principles of the weight distribution of the entire muscles.

A preliminary study about the value of individual muscles and bones as predictors of the carcass composition did reveal that within rather narrow ranges for the muscle and bone weight the prediction can be very precise with the aid of certain muscles and bones. It proved to be very difficult, however, to incorporate these components in easy-to-remove sample joints. The most promising part over a wide weight range is the shoulder.

Whether simplified sample joint methods can be used to replace carcass dissections depends largely on the type of experiment. In experiments with progeny groups or breed groups under standard feeding conditions the differences in carcass composition are in general small. For such experiments and for growth studies in which very accurate predictions are necessary most of the sample joint methods as indicated in the literature have too low a precision.

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RELATIONSHIP BETWEEN VISUALLY AND OBJECTIVELY ASSESSED CHARACTERISTICS AND OF SAMPLE JOINT DISSECTION WITH CARCASS COMPOSITION

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ABSTRACT

The body composition constitutes the main element of the real value of a carcass. But in practical conditions of commercialization, the carcasses are not jointed, and the body composition has to be estimated.

Thus we have studied the accuracy of different carcass characteristics in predicting carcass composition.

- The subjective criteria (conformation, fatness) which are traditionnally used for carcass assessment, or the different objective characteristics measured immediately after slaughter (carcass measurements, weight of the four feet, kidney fat...) give a very imperfect estimation of the carcass composition.
- It seems to be necessary to measure by dissection the composition of one or several wholesale joints to get a precise estimation of the proportion of the different components constituting the carcass.

INTRODUCTION

Through its very nature the I.T.E.B. is led to check an important number of animals at the moment of slaughtering and jointing. Thus having at its disposal an important and diverse animal material, it was logical to use this material to study the problems of estimating the carcass quality.

To begin with, we have studied how far it is possible to predict the body composition of an animal which in any case constitutes the main element in the real value of a carcass. The first results of this study are given below.

When one tries to estimate the composition of a carcass, different approaches are possible according to the checking facilities and the financial means at one's disposal.

We have considered three possible levels of prediction :

- either starting from a subjective assessment of the carcass, which corresponds to the conditions in which commercial transactions usually take place ; these being always based, in our market system, upon a visual appreciation of the carcass (or of the living animal),
- or starting from certain objective characteristics measured immediately after slaughtering and before cutting up the carcass,
- or again starting from the dissection of one or several wholesale joints, or sample joint taken from the carcass.

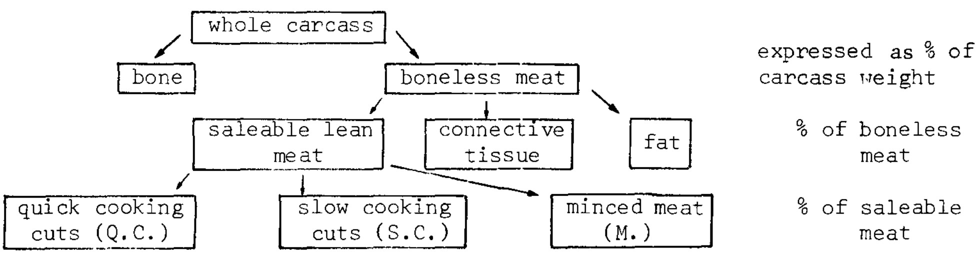
MATERIAL AND METHOD

- The results here given derive from 219 animals belonging to different breeds or crosses, the repartition of which will be found in table 1.

  In the choice of the animals our aim was to cover as much as possible the range of the commercial qualities most usually found in the French market. All our animals have not yet been slaughtered, which explains why our sample is not complete, but it is already possible to draw certain conclusions.

- The composition of the carcasses have been measured according to a standardised method. Each left half-carcass has been separated into saleable retail commercial joints, all the muscles having been deboned and trimmed ready for sale.

  We have selected the following items to characterize the composition of the carcasses :



The average characteristics of the sample are to be found in table 2.

We have successively studied the relations between the total carcass composition defined above and :

1) The composition of different parts of the carcass :

   - cuisse
   - aloyau
   - train de côtes (and also 11th rib)
   - carapaçon
   - basses côtes
   - collier
   - épaule

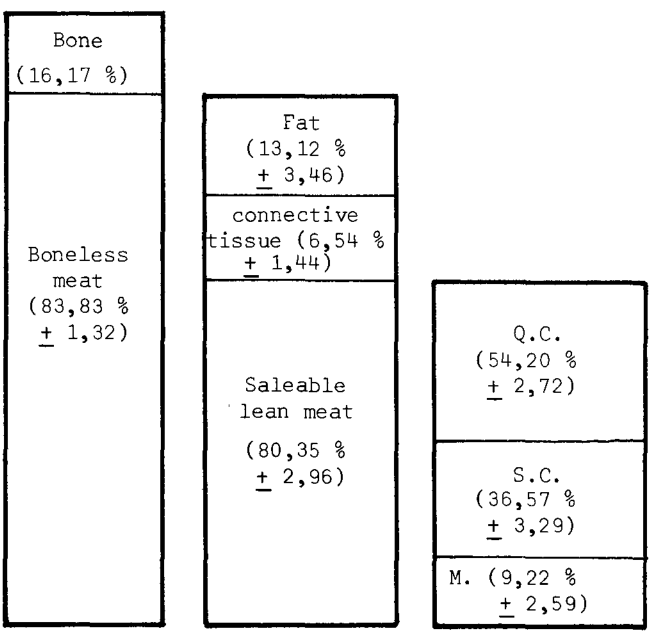
2) The objective characteristics measured at the time of slaughtering :

   - weight of the carcass
   - weight of the four feet (in % of carcass weight)
   - weight of kidney fat (" ")
   - weight of trimmable fat (" ")
   - measurements : length of carcass, depth of chest, length of leg, width of leg, and 4 different widths of loin

TABLE 1
REPARTITION OF THE ANIMALS

BREEDS	Young bulls	Heifers	Cows	Steers	Total
Normandy	34	20	10	15	79
Friesian	10	10	10	15	45
Maine-Anjou	10	10	10	10	40
Charolais	-	10	10	-	20
Salers	10	-	-	-	10
Limousin x Normandy	10	-	-	-	10
Holstein	10	-	-	-	10
Charolais x FFPN	-	-	-	5	5
TOTAL	84	50	40	45	219

TABLE 2
AVERAGE CHARACTERISTICS OF THE SAMPLE



CARCASS COMPOSITION

carcass weight

$\bar{x}$: 336,2 Kg

s : 60,6

conformation score

from E to R+
(F.R.A.N.C.E.)

fatness score

from 1 to 5
(S.I.B.E.V.)

3) Elements of visual assessment of the carcass :

- conformation score
- fatness scores (subcutaneous fat and internal fat)

in relation to the carcass weight which is always available.

Notion of "type"

It is normally impossible to study these relations for every breed and within a given breed for each sex, and anyway the composition of our sample did not permit it. Besides, under usual conditions, the breed is generally unknown at the carcass stage. We were therefore obliged to arrange the animals of our sample in groups.

Having noticed that the different groups of carcasses (breeds and sexes) could be fairly well differentiated on the basis of two ratios involving linear measurements: PP/LT and JS/LT*, from these two ratios we have calculated for each carcass an "objective type" (from 0 to 10)** which enabled us to divide up our sample into 4 groups:

- Group A : young bulls whose calculated type is > 6
- Group B : young bulls whose calculated type is < 6
- Group C : steers, heifers and cows, whose calculated type is > 2,5
- Group D : steers, heifers and cows, whose calculated type is < 2,5

Briefly one can say that the animals of type A are essentially young bulls of beef breed and Charolais crosses, or Normandy young bulls of very good quality. Type B is composed of Normandy, Friesian or Holstein young bulls. Type C is composed of heifers and steers in general, and also of beef breed cows. Type D is composed of dairy breed cows.

RESULTS

- The levels of relation (coefficients of correlation) between the total carcass composition and the different groups of prediction variables have been calculated for each of the 4 above defined types of animals (A, B, C, D), and will be found in tables 3, 4 and 5.

- One notices first that the average levels of correlation are not very high as a whole, especially those concerning the subjective elements of prediction.

  On the other hand, although no test of significance has been made, there seem to exist important differences in the level of correlation between the 4 types of carcasses for any given relation.

  Thus the most efficient estimator of any given characteristic is not necessarily the same for each type considered.

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* PP : depth of chest LT : length of carcass JS : length of leg

** Equation used for the calculation of the "type" (from 1 to 10)

$$T = 27,8 \frac{JS}{LT} - 83 \frac{PP}{LT} + 16,0$$

TABLE N° 3

Correlation coefficients between tissue components of the whole carcass (in percentage) and the corresponding components in the joints.

	TYPE	CUISSE	ALOYAU	TRAIN de COTES	11th RIB	CAPA	BASSES COTES	COLLIER	EPAULE
GROSS WT. MEAT	A	.86	.78	.82	.62	.88	.74	.81	.86
	B	.90	.86	.87	.47	.90	.72	.64	.90
	C	.86	.62	.80	.68	.83	.70	.61	.90
	D	.81	.77	.91	.54	.92	.72	.76	.83
FAT	A	.91	.95	.90	(2)	.96	.90	.90	.90
	B	.92	.91	.81	(2)	.92	.89	.79	.86
	C	.87	.91	.74	(2)	.94	.92	.87	.86
	D	.86	.97	.89	(2)	.96	.86	.91	.93
WASTE TRIMMINGS	A	.63	.69	.59	(2)	.43	.53	.56	.65
	B	.75	.81	.73	(2)	.64	.59	.33	.71
	C	.66	.65	.35	(2)	.40	.68	.61	.56
	D	.68	.66	.26	(2)	.83	.57	.70	.41
SALEABLE MEAT	A	.84	.94	.89	.89	.92	.91	.85	.76
	B	.81	.89	.84	.85	.89	.81	.85	.81
	C	.74	.88	.71	.76	.93	.71	.77	.60
	D	.61	.94	.82	.74	.93	.66	.88	.71
QUICK COOKING MEAT	A	.47	.28	-.07	(1)	(1)	.33	(1)	.81
	B	.44	.26	.19	(1)	(1)	.49	(1)	.72
	C	.61	.18	.33	(1)	.08	.82	.17	.87
	D	.46	-.26	.63	(1)	(1)	.85	(1)	.75
SLOW COOKING MEAT	A	.30	-.05	.28	(1)	.52	.39	.52	.73
	B	-.18	-.32	.36	(1)	.64	.73	.52	.57
	C	.54	-.23	.79	(1)	.36	.87	.19	.85
	D	.52	-.35	.64	(1)	.13	.85	(1)	.86
MINCE	A	.50	(1)	.11	(1)	.41	.44	.49	.79
	B	.55	(1)	.26	(1)	.05	.55	.64	.66
	C	.45	.53	.60	(1)	.57	.16	.43	.75
	D	.47	.61	.81	(1)	.43	(1)	(1)	.76
Number of cases in which R > .70		12	12	14		13	16	11	22
where R > .80		10	10	11		13	10	7	13

(1) Prediction is not possible from these joints.

(2) Fat and waste from the 11th rib included together during analysis. Only the relation between the saleable meat in the rib and carcass is available.

TABLE N° 4

Correlation coefficients between objective measurements after slaughter and the carcass composition.

	TYPE	HOT WEIGHT	LENGTH of CARCASS	DEPTH of CHEST	LENGTH of LEG	WIDTH of LEG	WIDTH OF LOIN 1	WIDTH OF LOIN 2	WIDTH OF LOIN 3	WIDTH OF LOIN 4	WEIGHT of the FEET%	KIDNEY FAT %	FAT TRIMMINGS
GROSS WT. MEAT	A	.16	-.30	-.36	-.38	.26	.35	.39	.50	.65	-.56	-.56	.07
	B	.34	-.52	-.41	-.41	.47	.61	.60	.77	.83	-.71	.20	-.21
	C	.30	.14	-.09	-.03	.46	.41	.32	.43	.59	-.66	.15	.23
	D	.46	.12	.09	.09	.55	.62	.41	.48	.37	-.77	.56	.67
FAT	A	-.40	-.51	-.49	-.56	-.32	-.34	-.09	.05	.30	.07	.62	-.14
	B	-.12	-.15	-.39	-.46	-.05	.14	.21	.30	.31	-.26	.63	.03
	C	.04	.10	.17	-.06	-.07	-.14	-.25	-.17	-.10	-.26	.55	.77
	D	.23	.05	-.08	.01	.31	.40	.24	.46	.31	-.50	.40	.77
SALEABLE MEAT	A	.49	.45	.34	.46	.45	.49	.26	.09	-.13	-.25	-.60	.11
	B	.32	.09	.18	.41	.22	.18	.15	-.07	.00	.04	-.60	-.14
	C	-.03	-.08	-.20	.01	.12	.13	.28	.23	.17	.14	-.54	-.73
	D	-.21	-.06	.07	.02	-.27	-.24	-.12	-.44	-.39	.36	-.28	-.73
QUICK COOKING MEAT	A	-.19	-.12	-.10	.05	-.28	-.13	-.16	-.22	-.35	.22	.21	-.30
	B	-.17	.12	.28	.23	-.06	-.09	-.01	.10	-.05	.27	-.15	-.38
	C	-.37	-.28	-.39	-.43	.00	-.02	.44	.39	.31	.19	-.30	-.06
	D	-.30	-.48	-.42	-.31	-.09	-.03	.12	.26	-.04	.08	-.08	.02
SLOW COOKING MEAT	A	-.54	-.32	-.22	-.30	-.46	-.40	-.28	-.61	-.38	.22	.34	.16
	B	-.15	.25	.09	-.01	-.23	-.40	-.54	-.49	-.51	-.01	.21	.52
	C	.25	.22	.37	.30	-.07	-.02	-.53	-.53	-.36	-.26	.38	.07
	D	.23	.40	.34	.27	.02	-.01	-.19	-.42	-.09	-.02	.02	-.16
number of cases in which R > .40		4	5	3	6	5	7	5	10	4	5	9	6
> .50		1	2	0	1	1	2	3	4	4	5	8	6

TABLE N° 5

Correlation coefficients between subjective scores plus weight given in the slaughter-house, and carcass composition.

	TYPE	HOT WEIGHT	SUBCUTANEOUS FAT SCORE	INTERNAL FAT SCORE	CONFORMATION
GROSS WT. MEAT	A	.16	.19	.07	.57
	B	.34	.43	.08	.74
	C	.30	.26	.08	.65
	D	.46	.73	.27	.37
FAT	A	-.40	.64	.54	-.02
	B	-.12	.65	.52	.26
	C	.04	.58	.39	-.21
	D	.23	.64	.21	.04
WASTE TRIMMINGS	A	-.29	-.02	-.11	-.48
	B	-.38	-.44	-.15	-.58
	C	-.13	-.48	-.13	-.19
	D	-.16	-.43	-.17	-.05
SALEABLE MEAT	A	.49	-.59	-.47	.21
	B	.32	-.41	-.44	.05
	C	-.03	-.54	-.41	.26
	D	-.21	-.59	-.19	-.02
QUICK COOKING MEAT	A	-.19	-.19	.00	-.25
	B	-.17	-.17	-.13	-.10
	C	-.37	-.49	-.26	.19
	D	-.30	-.13	-.33	-.01
SLOW COOKING MEAT	A	-.54	.21	.18	-.53
	B	-.15	.00	.18	-.38
	C	.25	.41	.26	-.25
	D	.23	.01	.30	-.01
MINCE	A	.53	-.06	-.13	.54
	B	.26	.11	-.11	.44
	C	.24	.11	-.06	.21
	D	.10	.33	-.06	.04

Example : (see table 5)

To estimate the percentage of boneless meat from subjective elements, the conformation score is the most efficient estimator for types A, B and C ; but it is the external fat score that gives the best predictive value for type D.

- By considering the above-mentioned results, and with the establishment of relatively simple prediction equations as our objective, we had to find, for each characteristic being predicted, those variables whose combination would provide the best multiple correlation.

- This search, which has been carried out for each of the 4 groups (A, B, C. D), has revealed in most cases, a definite progression of the values of the partial regression coefficients according to the type considered.

  To give an example, in the equation predicting the % of boneless meat from subjective variables the external fat score will bear the following coefficients :

Type A	- 3,16
Type B	+ 5,66
Type C	+ 29,30
Type D	+ 90,45

  This variation in the regression in relation to the type, which is explained when one understands this notion of "type", makes the use of an average predictive equation for all types utterly impossible. Therefore there remain only two possibilities :

  1) either use one equation only in which the calculated "type" of the carcass will be integrated. If we take up our previous example it gives the following equation :

$$Y = (-0{,}19T+0{,}33)X_1 + (-17{,}22T+105{,}8)X_2 + (-2{,}2T+12{,}42)X_3 + (4{,}94T+9{,}71)X_4 + 169{,}1T + 7331$$

Y = ‰ of boneless meat	X_3 = internal fat score
X_1 = carcass weight	X_4 = conformation score
X_2 = subcutaneous fat score	T = calculated "type"

  2) or divide the animals into several groups whose increasing averages of some particular characteristic reflect the change in type, and then calculate an equation for each of these groups.

  Comparison of both these methods has shown that the degree of accuracy reached is similar. Thus for the preceding example the coefficients of multiple correlation are respectively:

  0,68 when using the first method, and

  0,69 when using the second one.

CONCLUSION

- At the present stage of our interpretation and taking account of the method used, it seems that only the composition of the four parts constituting the forequarter needs to be taken into consideration as it provides an excellent estimate of the overall composition of the carcass and of all components (coeff. of correlation : 0,97 for the % of boneless meat, 0,99 for the % of fat, 0,95 for the % of lean meat...).

  This checking technique which involves the deboning and trimming of the forequarter, may mean a certain amount of work, but in the long run it saves time and money if you compare it to the deboning of the whole carcass.

- The intermediary level of checking which consists in measuring the composition of one joint of the carcass only, can be satisfactory for the prediction of certain components (e.g. : proportion of saleable lean meat using the 11th rib, R ≃ 0,80) but is unsatisfactory for the prediction of other components (e.g. prediction of the % of quick-cooking cuts using the "aloyau" (rump + sirloin) R ≃ 0,15, or the "cuisse" (round) R ≃ 0,49.).

- Finally, the appraisal of the overall composition either from subjective carcass assessment, or from objective measurements carried out when slaughtering, and which is both relatively simple and rapid, remains very unsatisfactory and can only be of use in a very wide sort of perspective, for instance as a basis for fixing market prices. These levels of checking would seem to be specially deficient when it comes to comparing groups of experimental animals. This inability of descriptive criteria (whether visual or objective) to predict carcass composition satisfactorily leads us to believe that, whatever care is taken in the checking and in the mathematical formulation, there may exist in fact a limit to the relation between external appearance and body composition.

In any case, this research must be extended, and in the light of our first results and working on a much more variable sample, we are now trying to find out whether other combinations of variables or a different mathematical approach can lead to better results.

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EEC Seminar on Criteria and Methods for Asssessment of Carcass and Meat Characteristics in Beef Production Experiments, Zeist, 1975.

BREED EFFECT IN ESTIMATING CARCASS COMPOSITION BY MEANS OF SAMPLE JOINT DISSECTION

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Abstract

Simple correlation between the tenth rib sample joint composition and carcass composition of young bulls of two pure breeds (Pezzata Nera and Pezzata Rossa) and of 6 types of F_1 crosses (Paternal breeds: Aberdeen Angus, Pezzata Rossa, Piemontese, Chianina, Marchigiana and Romagnola) were calculated.
Linear regression equations obtained for each breed and for each tissue were compared. Statistical analysis showed that regressions obtained on Chianina, Marchigiana and Romagnola crosses can be regarded as the same. The same was true for regressions calculated on pure bred Pezzata Rossa and crosses with the same paternal breed. No other grouping was possible. Multiple regression equations for the various breed groups were calculated and are presented.

Introduction

The knowledge of carcass composition (muscle, fat and bone content) can be considered a useful tool for the researcher to evaluate more completely the results of feeding trials and to estimate the usefulness of different breeds or crosses for beef production. Several researchers (Hankins and Howe, 1946; Ledger and Hutchinson, 1962; Martin and Torreele, 1962; Geay and Béranger, 1969; Lanari, 1973) have considered the problem and have presented various regression equations using sample joint composition to estimate carcass composition. Given that a diversity among breeds and crosses exists with regard to carcass composition the problem arises of applying such formulae to breeds different from those used to derive the èquations. In this note this problem will be examined and discussed.

Material and method

Right side and sample joint composition of young bulls used in this study is presented in table I. Two pure breeds, Pezzata Nera and Pezzata Rossa, and 6 different F_1 crosses obtained by breeding Aberdeen Angus, Chianina, Marchigiana,

TABLE 1. MEANS AND STANDARD DEVIATIONS OF THE WEIGHTS (KG) OF RIGHT SIDES, SAMPLE JOINTS AND THEIR TISSUES FOR DIFFERENT BREEDS AND CROSSES

PURE BREEDS	N° OF ANIMALS	RIGHT SIDE WEIGHT	SAMPLE JOINT WEIGHT	TISSUES WEIGHT IN SAMPLE JOINT			TISSUES WEIGHT IN RIGHT SIDE		
				MUSCLE	FAT	BONE	MUSCLE	FAT	BONE
PEZZATA NERA	29	120,96 ± 17,17	1,06 ± 0,19	0,64 ± 0,12	0,24 ± 0,08	0,18 ± 0,03	80,74 ± 13,66	20,33 ± 4,02	19,89 ± 2,55
PEZZATA ROSSA	29	141,54 ± 16,07	1,23 ± 0,19	0,78 ± 0,11	0,23 ± 0,07	0,22 ± 0,04	96,32 ± 11,43	22,47 ± 5,12	22,75 ± 3,26
F_1 CROSSES PATERNAL BREED									
ABERDEEN ANGUS	8	125,38 ± 3,38	1,25 ± 0,12	0,74 ± 0,07	0,33 ± 0,06	0,18 ± 0,02	73,33 ± 2,62	32,63 ± 3,48	19,42 ± 0,89
CHIANINA	8	145,23 ± 5,17	1,40 ± 0,11	0,90 ± 0,11	0,28 ± 0,04	0,22 ± 0,04	95,38 ± 3,32	23,96 ± 3,90	25,89 ± 1,03
MARCHIGIANA	8	143,45 ± 4,45	1,32 ± 0,14	0,88 ± 0,14	0,25 ± 0,05	0,19 ± 0,04	95,56 ± 7,47	21,83 ± 4,78	26,06 ± 1,48
PEZZATA ROSSA	11	141,31 ± 3,72	1,25 ± 0,10	0,79 ± 0,09	0,26 ± 0,04	0,20 ± 0,04	93,85 ± 5,12	23,86 ± 2,91	23,60 ± 1,81
PIEMONTESE	7	148,92 ± 2,64	1,53 ± 0,10	1,09 ± 0,10	0,19 ± 0,04	0,25 ± 0,05	108,88 ± 4,20	15,82 ± 2,62	24,22 ± 1,67
ROMAGNOLA	8	142,16 ± 3,01	1,41 ± 0,09	0,91 ± 0,05	0,27 ± 0,06	0,23 ± 0,05	93,42 ± 3,98	22,58 ± 3,89	26,16 ± 1,76

TABLE 2 - MULTIPLE REGRESSION EQUATIONS FOR ESTIMATING BEEF CARCASS COMPOSITION IN DIFFERENT BREEDS AND CROSSES

	PEZZATA NERA PURE BREED (n = 29)			PEZZATA ROSSA PURE BREED + F_1 CROSSES FROM P.R. BULL (n = 40)			F_1 CROSSES FROM ABERDEEN ANGUS BULL (N = 8)			F_1 CROSSES FROM ITALIAN WHITE BREEDS BULLS (n = 24)			F_1 CROSSES FROM PIEMONTESE BULL (n = 7)		
	Muscle	Fat	Bone	Muscle	Fat	Bone	Muscle	Fat	Bone	Muscle	Fat	Bone	Muscle	Fat	Bone
INTERCEPT	-16,015	15,382	2,281	2,717	- 0,171	-1,526	58,908	-59,625	3,665	7,506	-31,795	8,033	-12,385	12,664	-27,129
REGRESSION COEFFICIENTS OF INDIPENDENT VARIABLE															
SAMPLE TISSUE WEIGHT	50,896	51,685	19,501	66,203	64,715	26,647	-2,403	2,744	-17,505	52,231	77,759	18,428	36,955	90,532	22,496
SIDE WEIGHT	0,742	0,046	0,195	0,725	0,107	0,178	0,080	0,720	0,158	0,636	0,300	0,060	0,830	0,114	0,407
SAMPLE JOINT WEIGHT	-24,033	-12,377	-8,913	-49,884	-6,050	-5,104	3,516	0,881	0,729	-36,892	-6,762	-3,312	-27,896	-20,035	-9,771
MULTIPLE CORRELATION COEFFICIENT	0,989	0,789	0,879	0,974	0,912	0,855	0,190	0,756	0,537	0,855	0,929	0,525	0,940	0,996	0,950
STANDARD ERROR OF ESTIMATE	2,149	2,608	1,286	2,366	1,976	1,589	3,661	3,017	0,993	2,846	1,633	1,261	2,023	0,334	0,740

Piemontese and Romagnola bulls on dairy breed cows, were used. Data have been grouped according to the paternal breed since the two maternal dairy breeds used (Pezzata Nera and Bruna Alpina) did not affect carcass composition (Bonsembiante et al., 1975). All F_1 crosses were fed high nutritive level rations while the pure bred young bulls were fed rations widely different in nutritive value. Slaughtering, side preparation and dissection and sample joint cutting and dissection were performed according to the methods reported by Lanari (1972). Only the right sides with kidney fat were used. As sample joint the tenth rib steak containing the third dorsal part of the rib was employed. Because of previous results (Lanari, 1973) tissues and sample joint weights were used and multiple regressions were computed using side weight, sample joint weight and sample tissue weight as independent variables.

Results and discussion

Simple regressions between sample joint and total side compositions within each breed were computed.

By means of covariance analysis a general comparison among regressions was performed. The results show significant differences among regression coefficients and intercept values thus demonstrating great differences among breeds in carcass composition. By means of further comparisons it has been possible to combine data from different breeds reducing the number of groups from eight to five; hence it was possible to join in one group all F_1 crosses obtained from Chianina, Marchigiana and Romagnola bulls and in a second group Pezzata Rossa young bulls with their F_1 crosses.

Grouping of F_1 crosses from Chianina, Romagnola and Marchigiana breeds is justified by the common ancestral origin (Podolian) of these breeds and moreover by the use of Chianina bulls made during the formation of the Marchigiana breed (Borgioli, 1963).

Bonsembiante et al. (1975) revealed similarities among these crosses in carcass characteristics and also in some characteristics measured at slaughter.

Large differences among the remaining breeds were observed. Crosses from Piemontese bulls had carcasses with a high lean content and very low fat percentage. The reverse was true for Angus crosses.

Multiple regression equations for estimating carcass composition from sample joint composition have also been computed for the five groups. Owing to differences in numbers of animals within groups not all equations have the same precision; nevertheless these multiple regression coefficient values were high for all groups with the exception of those obtained from Angus crosses. Standard errors of estimates of the regression were also very high for the Angus group. Perhaps the introduction, or substitution, of new independent variables would improve the precision of estimates computed by these equations for our crosses. On the basis of these results it appears likely that equations for estimating carcass composition should be computed for each breed or for breeds or crosses having a common origin.

Because of the growing costs of research on large ruminants it could be useful for researchers in different countries to pool their efforts in order to discover variables that can be used in all breeds or crosses to evaluate carcass composition. In this regard it is questionable whether the sample joint dissection technique is still an up-to-date method or if it can be abandoned for less expensive and more precise techniques.

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PREDICTION OF THE LEAN CONTENT OF STEER CARCASSES OF DIFFERENT BREED TYPES FROM THE LEAN CONTENT OF SAMPLE JOINTS

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Abstract

Dissection data for 753 steer carcasses of 17 breed-type x feeding system groups were used to examine the prediction of the lean content in the side from the lean content of sample joints.

Two methods of formulating the prediction equation were compared: (A) with weight of lean in the joint and side weight as the independent variates and (B) with percentage lean in the sample joint as independent variate. With Equation A, the shin joint was shown to offer the best compromise between cost and precision. When Equation B was used, the shin joint was shown to be a very poor predictor and the fore rib was suggested as the best compromise. Of the two equations, B gave a substantially better prediction with all joints except the shin and leg.

The stability of Equation B between breed-type x feeding system groups was examined for different sample joints. Joints which gave the most precise prediction tended to have the most stable prediction equations. The equations for the shin and leg were very unstable, whereas those for the coast and rump were particularly stable.

Introduction

Although there are many reports of analyses comparing the precision of different sample joints as predictors of carcass lean content, two important questions remain unanswered. These are as follows.

1. How should the prediction equation be formulated to give the most precise prediction of lean content? For example, is it better to use the weight of lean in the joint or the weight of lean expressed as a percentage of the joint weight as an independent variate.

2. How accurately do regression equations constructed for one'group' of carcasses predict the lean content of another 'group' differing, for example, in breed, sex or plane of feeding?

Question 1: In published analyses, two main prediction equations have been used:

	Dependent variate	Independent variates	
Equation A	Weight of lean in the side	Weight of lean in sample joint	Weight of side
Equation B	Weight of lean in side as a percentage of side weight	Weight of lean in sample joint as a percentage of the joint weight	Weight of side

In many cases, Equation B has been simplified by the exclusion of side weight.

It is evident that the ranking of sample joints differs depending on which equation is used. When Equation A is used, there is relatively little difference in precision between joints and the shin is normally selected because it is convenient and cheap to dissect (for example, Cole et al, 1960; Butterfield, 1965; Hinks and Prescott, 1974). On the other hand, with Equation B, the shin joint is shown to be a very poor predictor indeed and other joints, especially rib joints have generally been selected (for example, Ledger et al, 1973; Kempster et al, 1974). Equation B has been used almost exclusively in analyses designed to test rib joints alone (for example, Crown and Damon, 1960; Tayler, et al, 1961; Ledger and Hutchison, 1962).

The basic difference between the two equations is that one includes joint weight (although only as the divisor for percentage lean in the joint) and the other does not. The recalculation of Callow's (1962) data by Harrington and King (1963) is most relevant in this context because joint weight was added into an A type equation. They found that whereas the precision of the shin joint was little affected, there was a substantial improvement in precision for most of the other joints.

Question 2: Many writers have pointed out the potential dangers of using prediction equations in circumstances different to those in which they were constructed, but there have been few analyses to test the stability of prediction equations; sample sizes have generally been too small or the data insufficiently variable in origin to do this. Ledger and Hutchinson (1962) found that the prediction of total fat in the carcass was improved by separate prediction equations for steer and cow carcasses. Williams et al. (1974) examined the stability of regression equations by comparing predicted values with actual values. However, the three groups in their study differed in breed mix, proportion of steers and heifers and dissection procedure, and it is not possible to distinguish the effects of these various factors on the results.

The analysis reported in the present paper was carried out to examine these two questions using a very large body of dissection data for steer carcasses of different breed-type x feeding system groups.

Material and methods

Dissection data for 753 steer carcasses of 17 breed type x production system groups were used in the study. The carcasses were a sample of those evaluated by the Meat and Livestock Commission over the past six years. Details of the groups are given in Table 1. In most cases all the cattle in a particular group came from the same trial and were grown under similar conditions. Exceptions were groups 4, 8, 9 and 12 each of which comprised cattle from two or more trials considered sufficiently similar to be pooled. Group 10 consisted of commercial cattle of miscellaneous origin and group 14 commercial cattle which were predominantly Welsh Black crosses. In the table feeding regimens have been classified in broad terms as intensive (cereal-based diets fed from weaning to slaughter) or semi-intensive (cereal feeding plus a period of forage feeding). The cattle in group 11 were suckled calves intensively finished.

The left side of each carcass was dissected using the procedure described by Cuthbertson et al. (1972). After removal of the kidney, perinephric and retroperitoneal fat, cod fat and M. psoas major, the side was divided into 11 standardised commercial joints defined either by reference to skeletal points or by separation of adjacent muscles (Figure 1). The joints were separated using butcher's knife into lean, subcutaneous fat, intermuscular fat, bone and waste.

The data were analysed using standard statistical techniques. Regression equations were applied to all the data ignoring groups (referred to as the common line situation), common slopes were applied within groups (common slope situation) and individual regression lines were applied to each group (individual line situation). The stability of prediction equations between groups was assessed from the reduction in the residual standard deviation (increase in the precision of prediction) between the common line situation and the pooled within group (individual line) situation. Also, the mean for

TABLE 1

Description of the groups

Group	Breed type and feeding system group (sire given first)	Number of animals	Approximate age (months)		Side weight‡ (kg)		Weight of lean in side (kg)		Percentage lean in side	
			Mean	Range	Mean	SD	Mean	SD	Mean	SD
1	Ayrshire (I)	27	13	10 - 15	103.1	5.05	60.0	3.43	58.2	2.31
2	Angus x Friesian (SI)	18	21	20 - 22	104.0	4.06	62.9	2.67	60.5	2.13
3	Hereford x Friesian (I)	31	14	12 - 15	104.1	12.13	62.1	6.50	59.8	3.49
4	Friesian (I)	106	13	10 - 16	108.3	8.65	67.5	5.62	62.4	3.11
5	Limousin x Friesian (I)	25	14	12 - 15	108.9	16.00	71.1	9.44	65.5	3.03
6	Charolais x Friesian (I)	49	11	10 - 13	109.6	3.40	70.1	3.59	63.9	2.50
7	Limousin x Friesian (SI)	11	18	15 - 21	112.9	6.07	74.7	4.34	66.1	1.52
8	Hereford x Friesian (SI)	66	18	17 - 20	113.9	10.00	70.5	6.67	61.9	2.96
9	Simmental x Friesian (I)	65	15	12 - 16	116.5	12.83	72.5	7.87	62.3	2.57
10	Miscellaneous commercial cattle	65	-	-	120.7	20.80	74.3	12.04	61.7	3.42
11	Angus crosses † (intensively finished)	29	17	16 - 18	122.1	9.42	66.8	5.25	54.8	2.81
12	Friesian (SI)	72	19	17 - 22	126.3	11.79	78.6	7.59	62.3	2.74
13	Simmental x Friesian (SI)	51	19	16 - 21	127.0	23.27	82.5	13.51	65.2	2.47
14	Commercial cattle (Predominantly Welsh Black and crosses)	79	-	-	127.5	12.29	81.2	7.93	63.7	2.18
15	Friesian x Ayrshire (SI)	25	21	19 - 23	132.5	11.44	78.8	6.22	59.6	2.38
16	South Devon x Friesian (SI)	10	18	17 - 19	132.9	11.21	82.6	5.74	62.3	2.45
17	Simmental x Ayrshire (SI)	24	21	19 - 23	138.9	11.48	85.2	5.39	61.5	3.12
	Pooled within groups					12.95		7.81		2.79
	Overall	753			117.9	15.95	73.2	10.18	62.1	3.54

† Crosses with Blue-Grey and Hereford x Friesian

‡ Excluding KKCF

I Intensively fed

SI Semi-intensively fed

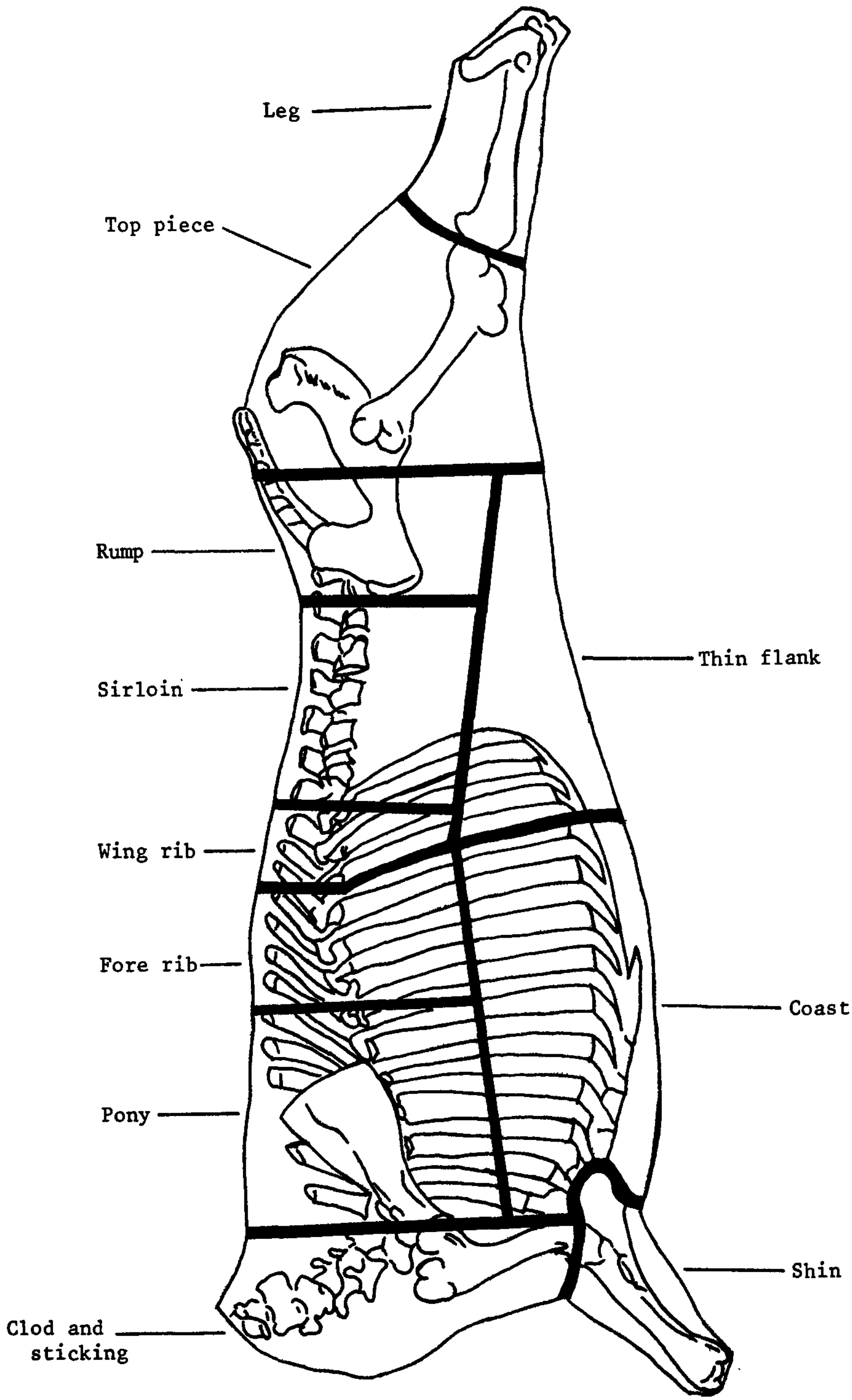

Fig. 1. Side of beef divided into standardised commercial joints.

TABLE 2

Residual standard deviations pooled within groups (common slope) for different prediction equations

Equation		A	B_1	B_2	C
Dependent variate		Wt. of lean in side (kg)	Percentage lean in side		
Independent variates	1.	Wt. of lean in joint	Percentage lean in joint	Percentage lean in joint	Wt. of lean in joint
	2.	Wt. of side		Wt. of side	Wt. of side
SD of dependent variate		7.81	2.79	2.79	2.79
Residual df		734	735	734	734
Joint:	Shin	2.66	2.56	2.44	2.21
	Coast	2.57	1.13	1.12	2.14
	Clod & sticking	2.76	1.61	1.49	2.28
	Fore rib	2.86	1.34	1.32	2.38
	Pony	2.71	1.17	1.14	2.29
	Leg	2.85	2.42	2.32	2.38
	Thin flank	3.19	1.53	1.52	2.64
	Rump	2.83	1.50	1.50	2.36
	Sirloin	2.79	1.46	1.46	2.32
	Wing rib	2.94	1.50	1.50	2.45
	Top piece	2.07	1.21	1.21	1.73

each group predicted from the common regression line was compared with the actual mean.

Results and discussion

Table 2 gives the residual standard deviations pooled within groups (common slope) for the prediction of lean content in the side from Equation A and the two types of Equation B (B_1 excluding side weight and B_2 including side weight as an independent variate). Using Equation A, the top piece gave the most precise prediction followed by the coast and shin joints. The top piece and coast are expensive to dissect and on the basis of these results the shin joint would be the obvious choice. However, using either B_1 or B_2 (which differed very little) the coast and pony were the most precise predictors followed by the top piece and fore rib. The shin and leg joints were very poor predictors in comparison with the other joints. On the basis of these results, the fore rib would probably offer the best compromise between cost and precision.

Table 2 also shows (Equation C) the residual standard deviations for the prediction of percentage lean in the side from the weight of lean in the joint and side weight (essentially the same as Equation B_2 without joint weight). The precision of the joints other than the shin and leg joints is shown to be much lower than for Equation B_2, demonstrating the importance of including joint weight in the equation. The practical importance of these results is that, if joint weight is not included in equations:

1. the precision of the shin and leg joints is exaggerated relative to the precision of other joints,

2. a substantial increase in precision, which could be obtained at no extra cost, is being lost when joints other than the shin and leg are used.

An analysis is currently being carried out on these data to establish whether there is much increase of precision when the weight of lean in the joint and joint weight are used as separate independent variates instead of percentage lean in the joint as a single variate.

The stability of Equation B_1 for predicting percentage lean in the side in cattle of different breed-type x feeding regimen groups is examined in Table 3. Stability, as judged both by the reduction in residual standard deviation between the common line and individual line situations and by the average deviation of predicted means from the actual values, tended to increase with the precision of the different joints. Prediction equations for the shin

TABLE 3

Prediction of percentage lean in side from percentage lean in sample joints (Equation B_1): residual standard deviations and average differences between predicted and actual breed-type group means

		Overall RSD (common line)	RSD pooled within groups (common slope)	RSD pooled within groups (individual lines)	Predicted † - actual mean
Residual df		751	735	719	
Joint:	Shin	3.25	2.56	2.49	±1.86
	Coast	1.23	1.13	1.12	±0.43
	Clod & sticking	1.78	1.61	1.59	±0.65
	Fore rib	1.50	1.34	1.32	±0.63
	Pony	1.32	1.17	1.15	±0.54
	Leg	3.09	2.42	2.39	±1.79
	Thin flank	1.88	1.53	1.50	±0.92
	Rump	1.55	1.50	1.49	±0.39
	Sirloin	1.62	1.46	1.46	±0.64
	Wing rib	1.71	1.50	1.49	±0.68
	Top piece	1.34	1.21	1.21	±0.48

† Difference between the predicted mean, computed using the common regression line, and the actual mean for each breed-type group, averaged over all groups ignoring the sign of the difference.

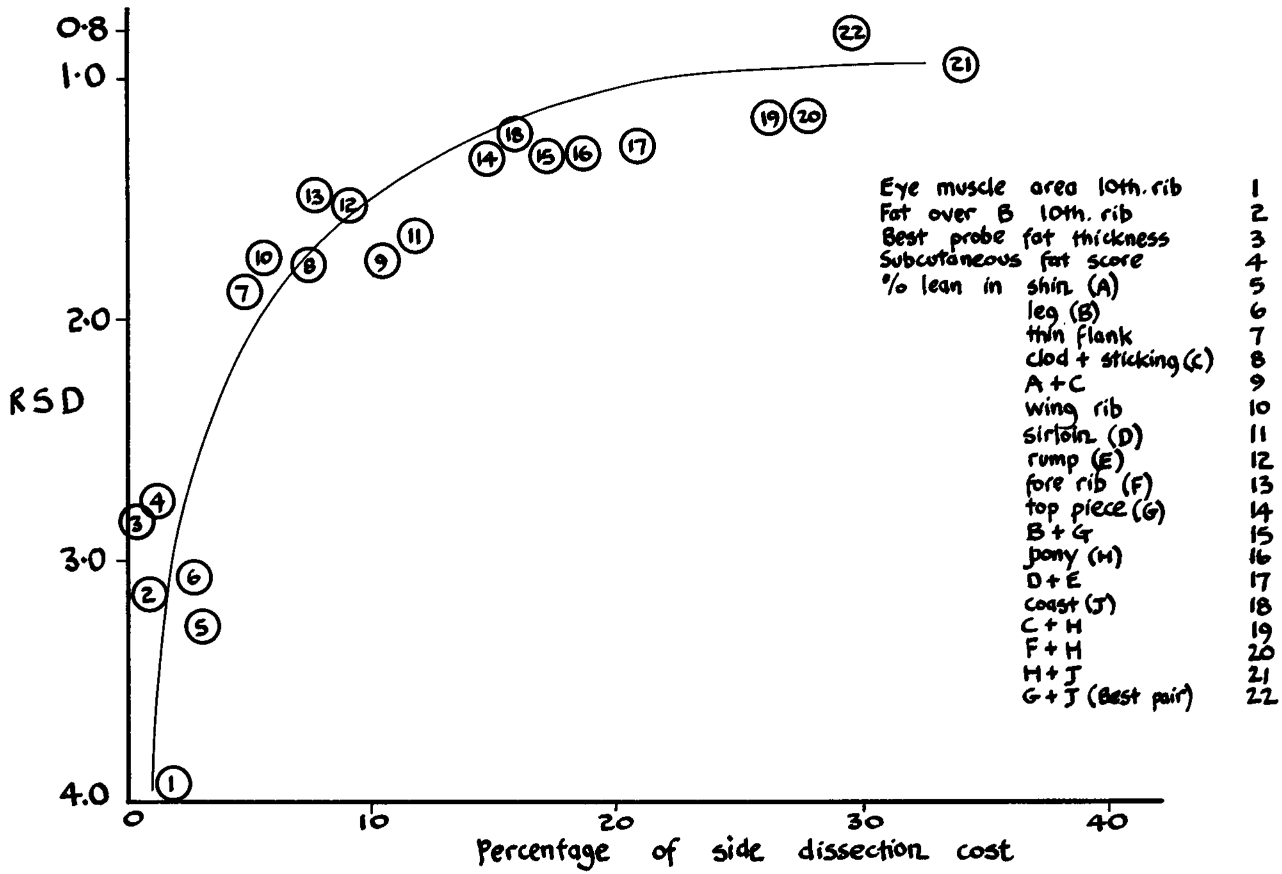

Fig. 2. Precision against cost for predicting percentage lean in side.

and leg joints were particularly unstable between groups indicating that these joints should be avoided unless prediction equations are obtained for the sample of cattle in which they are to be used. In contrast, the coast and rump were particularly stable and would be recommended for use in circumstances where it is not possible to estimate individual prediction equations.

Note on choice of predictor of leanness

The method chosen for predicting the lean content of carcasses will depend on a number of factors, such as the resources available for evaluation, the accuracy of the answers required for a particular project, and the cutting procedures in operation in the particular country or part of the country. Each individual worker has his own reasons for choosing a particular procedure, but it is important that care is taken in choosing the best procedure for each particular set of circumstances. In this connection, it is relevant to consider the stability of the prediction equations in different situations.

Figure 2 illustrates, for the sample of carcasses used for the analysis reported in this paper, the precision of some alternative predictors (in terms of the residual standard deviation of lean percentage) against the cost of obtaining the measurements. In the case of sample joints, the cost ascribed to each joint includes overheads, labour and joint depreciation, but does not include the depreciation of the carcass resulting from the removal of the sample joint. In some commercial situations removal of a sample joint from the carcass may incur substantial loss.

It is clear from Figure 2 that one can achieve quite low RSDs without incurring very heavy costs. However, the choice of sample joint is important since the worst sample joints (shin and leg) are no better predictors than a simple subjective score for subcutaneous fat. Only a few combinations of measurements are presented in the Figure, and further work is in hand to determine other combinations which may offer better value for money.

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DISSECTION OF THE THREE RIB JOINT (7TH-8TH-9TH) AND CARCASS BLOCKINESS AS ESTIMATES OF CARCASS VALUE

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Abstract

The usefulness of the sample joint dissection of the three rib cut 7-8-9 is restated ;the error of prediction of the carcass composition does not exceed 1%.
The blockiness of the carcass is used for carcass assessment. This measure may be useful in order to estimate directly carcass value and indirectly carcass composition. The development of a convenient method for estimation of the degree of fatness in carcasses would increase considerably the accuracy of prediction.

1. The sample joint 7-8-9 as a measure of carcass composition

All research concerning beef carcass composition reaches the conclusion that only complete anatomical dissection of the carcass into lean meat,fat and tendons,and bones gives an exact description of carcass composition.To avoid elaborate manipulation and financial losses the Study Centre for Meat Production applied the simplified method of the dissection of the three rib cut 7-8-9 to predict carcass composition in the progeny of A.I. bulls. Several papers published by staff members (Martin et al.) demonstrate a sufficient accuracy for the estimation of % muscle and bone in carcasses.

When % muscle is estimated by simple linear regression of the type $\% Y_{(carcass)} = a_0 + a_1(\% X_{(7-8-9)})$ some of the characteristics of these estimators are:

type of animal	a_0	a_1	r^2	Residual S.D.
Young bulls (n=24)	(a) 16,80	0,8050	0,9638	1,02
Veal (n=38)	(b) -6,42	1,1512	0,8595	1,35
Heifers (n=10)	(c) -1,99	1,1064	0,9666	0,86
Steers (n=5)	(d) 24,94	0,6722	0,9604	0,69
Cows (n=4)	(e) -41,60	1,8980	0,9171	0,92

(a) Intensively fattened young bulls,450kg (IO);480kg (I4)

(b) Dutch type,≈ 150kg,I4 weeks

(c) Intensively fattened up to 450 kg(4),the others bought at random (≈ 550 kg)

(d),(e) Bought at random;steers ≈ 600kg, cows ≈ 740kg

In the same way the estimators for % bone are:

type of animal	c_0	c1	r^2	Residual S.D.
Young bulls (n=24) (a)	6,65	0,4930[illegible]	0,6212	0,76
Veal (n=38) (b)	5,74	0,6578	0,4819	1,11
Heifers (n=10) (c)	0,31	0,9056	0,6396	0,62
Steers (n=5) (d)	2,48	0,7776	0,9801	0,14
Cows (n=4) (e)	-3,57	1,1965	0,8779	0,68

(a),(b),(c),(d),(e) as before

G.Torreele found that,when in addition to $\%B_{3R}$, the weights of both carcass halves (weight of carcass) and the weights of the 4 feet (offal) is known, $\%B_H$ can be estimated by means of multiple regression equations relating $\%B_H$ to $\%B_{3R}$ and the proportion (weight of the 4 feet/0,01 weight of the carcass)=(P/0,01 HH) in the form $\%B_H = C_0' + C_1' (\%B_{3R}) + C_2' (P/0{,}01\ HH)$. The introduction of the last variable considerably increases the accuracy of the estimation of % bone.

type of animal	c_0'	c_1'	c_2'	r^2	Residual S.D.
Young bulls(n=24) (a)	2,89	0,3672	2,1888	0,7960	0,57
Veal (n=38) (b)	0,89	0,4637	2,2484	0,7074	0,84
Heifers(n=10) (c)	1,76	0,4729	2,0432	0,7759	0,49

(a),(b),(c) as before

By interpretation of the residual standard deviations of the regressions it seems that the three rib cut procures reliable information for the estimation of carcass composition. For this reason the rib joint 7-8-9 is intended for further investigations e.g. concerning commercial and economic carcass value estimation.

2. Assessment of carcass value

2.1. Considerations

The animal factors related to carcass value are principally conformation and carcass weight (considering breed,sex...) and the complementary degree of fatness and bone content of the carcass.
The assessment of carcass conformation may be done in objective (linear measurements) or subjective (eye,photographs,slides.....) ways. Some general reflections are:

- single measurements(carcass length,depth of thorax....) give very poor information about conformation.
- combined measurements incorporated into multiple regression equations increase accuracy but are not convenient for prompt assessment (commercial approach).
- visual assessment(slides...) of conformation (fleshiness) may give useful information ;this procedure however requires well coached judges to estimate the specific nature of conformation characteristics.
- lastly conformation probably cannot be put into a geometrical or mathematical matrix;only an approximation of the real substance of conformation may be obtainable.

2.2. Preliminary data

2.2.1. Slaughter data

The Study Centre evaluates an approach to conformation assessment by the "blockiness" of the carcass(cold carcass weight divided by carcass length) which principally involves the commercial carcass value,and the "blockiness of meat",fat and bones in the carcass which represents an economic criterion of carcass value.
Both carcass weight and carcass length are objective measurements and are easy to obtain.
At the end of 1974 the slaughterhouse of the Faculty of Agricultural Sciences-R.U.G.,came into operation.All experimental animals and a restricted number of marketable animals have been slaughtered there.
Market bulls gave the following data for blockiness of the half-carcass:

N	Weight range	Carcass weight (kg)	Carcass length (cm)	Blockiness of the half carcass
2	300-325	320,2 ± 3,18	127,5 ± 0,71	1,253 ± 0,032
17	325-350	340,9 ± 7,92	131,2 ± 4,23	1,299 ± 0,062
35	350-375	363,9 ± 8,80	134,9 ± 2,91	1,349 ± 0,042
38	375-400	386,9 ± 6,93	137,3 ± 2,65	1,407 ± 0,037
28	400-425	412,0 ± 6,45	138,2 ± 3,64	1,489 ± 0,040
24	425-450	439,1 ± 6,28	141,6 ± 4,13	1,536 ± 0,090
11	450-475	463,9 ± 8,33	143,4 ± 2,46	1,616 ± 0,033
5	475-500	484,3 ± 5,43	144,0 ± 2,12	1,676 ± 0,036
4	500- 525	516,4 ± 4,92	150,7 ± 2,99	1,711 ± 0,045

These data immediately show that the blockiness of the carcass must be interpreted within limited weight ranges of carcasses.
The linear regression equation for carcass length related to carcass weight X based on the means for the different weight classes is given by: Y= 95,72 + 0,1040 X (r=0,98;Residual $S.D._{regr.}$ = 1,33cm).
This means that a carcass whose characteristics comply with (95,72 + 0,1040 X > Y) represents a better blockiness than the mean carcass in the considered weight range,therefore a +value is attributed.
A practical approach may be: Carcass weight/10 +100 - length ≷ 0 which produces adjusted + and - values.
Similar regression equations should be calculated within all weight ranges,breeds,sexes ... to obtain the exact estimators of carcass blockiness.

2.2.2. Dissection data

Anatomical dissections of the three rib cut 7-8-9 for 80 experimental bulls intensively fattened up to a live weight of 450 kg (progeny-test),and belonging to four belgian breeds yielded the estimations of carcass composition.
Calculated coefficients of determination show that the blockiness of the carcass (mean wt. ≈ 275 kg) explains 60 % of the variation in the

blockiness of lean meat in the carcass . The blockiness of the carcass however is not directly an estimator of the relative amount of muscle in the carcass,but the absolute amount of meat per cm carcass explains 70 % of the variation in % meat content.

data	breeds				total
	A(n=20)	B(n=20	C(n=20)	D(n=20)	n=80
Carcass weight	275,6± 9,4	276,4±5,2	270,6±8,4	281,1±8,3	275,9±8,7
% lean meat	64,83±3,57	64,87±3,96	62,97±2,45	68,05±3,04	65,18±3,73
Blockiness of half-carcass (g/cm)	1111±54	1116±36	1115± 37	1151±47	1123±46
Meat blockiness (g/cm)	724±67	724±52	702±42	788±35	735±59
Carcass length	123,1±2,13	123,2±2,28	121,0±2,22	121,9±2,16	122,3±2,35

A: West Flemish Red ,B: East Flemish Red Pied
C: Campine Red Pied, D: Central and Upper Belgian

Coefficients of regression(b_1,b_2) and determination (r^2) are given for the relations:
1° carcass blockiness related to meat blockiness
2° relative meat content in the carcass related to me at blockiness
3° relative meat content in the carcass related to carcass blockiness

	COEFFICIENTS	A	B	C	D	Total (n=80)
1	b_1	1,0550	0,7973	0,9474	0,4523	0,9736
	b_2	0,0683	0,3833	0,6966	0,6073	0,5854
	r^2	0,0720	0,3056	0,6600	0,2747	0,5700
2	b_1	0,0174	0,0118	0,0149	0,0024	0,0132
	b_2	49,7517	67,5650	50,1047	17,3795	52,2932
	r^2	0,8671	0,7965	0,7486	0,0414	0,6903
3	b_1	0,0094	0,0013	0,0058	-0,0052	0,0041
	b_2	41,5251	15,0010	26,4181	-22,2500	27,0871
	r^2	0,3909	0,0013	0,0058	0,1158	0,1111

In general conclusion this investigation indicates that in order to obtain an exact prediction of the carcass composition the dissection of joints (especially the three rib cut 7-8-9) cannot yet be rejected.
If a good and convenient estimator could be found to measure the degree of fatness of carcasses, the blockiness of the carcass as a reference basis (+or- values) may be helpful in estimating carcass value.

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THE SIGNIFICANCE OF BREED DIFFERENCES IN FAT DISTRIBUTION TO THE PREDICTION OF BEEF CARCASS COMPOSITION

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Abstract

Dissection data for 643 steer carcasses of 15 breed-type x feeding system groups were used to examine the distribution of total fat between subcutaneous fat, intermuscular fat, kidney knob and channel fat (KKCF) and cod fat depots. The analysis was carried out with special reference to the problem of predicting total fat content from measures of a single depot.

Important differences existed between the groups in fat distribution, breeds and crosses at the dairy end of the spectrum tending to have less subcutaneous fat and more KKCF than those at the beef end of the spectrum.

The differences in fat distribution led to substantial bias for some groups when the percentages of intermuscular fat and total fat in the side were predicted from percentage subcutaneous fat. The bias was less when both KKCF and subcutaneous fat were used as predictors.

Introduction

Breed differences in fat distribution have been demonstrated by a number of workers including Ledger (1959), Butterfield (1965), Anon (1966) and Pomeroy and Williams (1974). The evidence indicates that dairy breeds tend to deposit a higher proportion of their total fat internally and a lower proportion subcutaneously than beef breeds.

The existence of breed variation in fat distribution is a potential complication when predicting the overall fat content of carcasses from measures of a single depot. It would present a problem, for example, in breeding schemes and breed comparisons when carcass composition in the live animal is predicted from subcutaneous fat depths or areas measured ultrasonically, and in commercial classification when composition is predicted from subjective appraisal of external fatness or from measures of subcutaneous fat thickness. Pomeroy and Williams (1974) demonstrated that differences in fat distribution between extreme dairy-type and beef-type cattle may produce substantial bias when subcutaneous fat weight is used to predict intermuscular fat weight. They found that the degree of bias was less when both KKCF and subcutaneous fat

TABLE 1

Means and standard deviations of total fat weight in the side and depots as a percentage of total fat weight

Group	Total fat (kg)		Intermuscular fat (%)		Subcutaneous fat (%)		KKCF (%)		Cod fat (%)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1 Ayrshire (I)	33.4	4.82	47.7	3.47	28.2	3.12	19.8	4.21	4.3	0.54
2 Angus x F (SI)	30.1	3.98	48.5	2.16	29.0	1.81	18.0	2.34	4.5	0.51
3 Hereford x F (I)	27.9	6.74	47.3	2.84	35.3	3.45	12.7	2.50	4.8	0.65
4 Friesian (I)	26.5	5.45	50.9	2.95	28.6	3.07	16.2	3.37	4.3	0.65
5 Limousin x F (I)	23.7	6.75	50.2	2.64	29.5	3.86	15.7	4.06	4.6	1.19
6 Charolais x F (I)	25.3	3.82	52.8	2.93	27.9	2.98	14.4	2.48	4.9	0.73
7 Hereford x F (SI)	28.0	5.90	49.3	3.03	31.3	3.51	14.6	2.49	4.7	0.63
8 Simmental x F (I)	28.8	6.06	50.9	3.30	29.0	2.79	15.8	2.95	4.4	0.74
9 Angus x	44.3	6.26	46.6	2.34	36.0	2.42	12.9	1.71	4.5	0.64
10 Friesian (SI)	31.2	8.77	49.6	2.91	27.4	2.91	18.4	3.62	4.5	0.66
11 Welsh Black x	27.3	5.13	46.9	3.13	31.5	4.02	16.3	3.46	5.2	0.93
12 F x Ayrshire (SI)	41.5	7.29	48.3	3.21	26.4	3.15	21.3	3.71	4.0	0.48
13 S. Devon x F (SI)	34.9	7.73	50.1	1.98	26.7	2.68	19.0	2.21	4.2	0.70
14 Simmental x Ayrshire (SI)	39.6	7.95	49.7	2.23	25.6	2.81	20.4	2.99	4.3	0.53
15 Simmental x F (SI)	38.1	7.20	50.2	3.27	27.9	3.08	17.1	3.30	4.8	0.60
Pooled within group SD		6.17		2.96		3.19		3.16		0.72
Overall mean	30.1		49.5		29.5		16.4		4.6	

F = Friesian
I = Intensively fed
SI = Semi-intensively fed

weights were used as predictors.

The present paper examines the complications of breed differences in fat distribution to the prediction of beef carcass composition.

Material and methods

Dissection data for 643 steer carcasses of 15 breed type x feeding system groups were used in the study. The groups were those described by Kempster, Cuthbertson and Jones (another paper submitted to this Seminar) with certain exceptions. The miscellaneous commercial group and the semi-intensive Limousin x Friesian groups were not included in the present study, and the semi-intensive Simmental x Friesian group comprised only 17 carcasses.

The left side of each carcass was dissected using the procedure described by Cuthbertson, Harrington and Smith (1972).

The data were analysed using standard statistical techniques. Overall correlations (ignoring groups) and pooled within group correlations (common slope) were computed between the percentages of subcutaneous fat, intermuscular fat, kidney knob and channel fat (KKCF), cod fat and total fat (sum of the four depots mentioned) in the side. The regression relationships for the prediction of the percentages of intermuscular fat and total fat in the side from percentage subcutaneous fat were examined in detail.

Results

The partition of total fat between the four depots is shown in Table 1. Intermuscular fat was the greatest contributor to total fat in all groups (accounting, on average, for 49.5% of total fat) followed by subcutaneous fat (29.5% of total fat). KKCF was the most variable depot within groups (pooled within group coefficient of variation (CV) = 19.3%) followed by cod fat (CV = 15.7%) and subcutaneous fat (CV = 10.8%); intermuscular fat was least variable (CV = 6.0%).

There were major differences between breeds in fat distribution. For example, carcasses of the Ayrshire group contained 11 kg less fat in the side than those of the Angus cross groups yet they contained 1 kg more KKCF in the side. Carcasses from the Friesian x Ayrshire and Simmental x Ayrshire groups also had a high proportion of KKCF in relation to their overall fatness. Kempster, Cuthbertson and Harrington (paper recently submitted to Animal Production) examined in detail the breed differences in fat distribution. Adjustment of the group means to equal total fat weight did not produce any major alteration to the differences in fat distribution between groups shown in Table 1.

The relative magnitude of the correlations between total fat and the depots as a percentage of side weight were similar whether computed overall (ignoring groups) or pooled within groups, and increased in the order KKCF, cod fat, subcutaneous fat and intermuscular fat (Table 2). Covariance due to the part-whole relationship between depot and total fat would be expected to increase the correlations for the larger depots relative to those of the smaller depots. It is notable, therefore, that the correlation with KKCF was lower than with cod fat despite the fact that KKCF was some four times as large. KKCF was also less highly correlated with intermuscular fat than was cod fat.

The regression relationships for predicting the percentages of intermuscular fat and total fat in the side from subcutaneous fat percentage are examined in Table 3. Residual standard deviations within groups for intermuscular fat ranged from 0.69 to 1.40 with a pooled value (individual regression lines) of 1.18. The range for total fat was 1.33 to 2.63 with a pooled value of 1.91. Differences between slopes were statistically significant for both intermuscular fat and total fat but they were relatively unimportant; application of common slopes increased the residual standard deviations by only 0.03 and 0.08 respectively. There were important differences between intercepts in both cases.

The mean intermuscular fat and total fat percentages for each group predicted from the overall regression lines are compared with the actual values in Table 3. Intermuscular fat means for the Ayrshire, Friesian x Ayrshire and SimmentalxAyrshire groups were underestimated by 1.6% or more while those for the Welsh Black cross and intensive Hereford x Friesian groups were overestimated to a similar degree. The average deviation was ± 0.9%. The deviations for total fat showed a similar pattern in terms of ranking and relative differences between groups but the differences were larger, the average deviation being ± 1.7%.

The prediction of percentage intermuscular fat and percentage total fat in the side from a multiple regression combining subcutaneous fat and KKCF percentages was also examined. The combination of predictors gave a more precise prediction in both cases (residual standard deviations about common lines were 1.38 and 1.41 respectively). There was also an important reduction in bias particularly for the prediction of total fat, the average deviation

TABLE 2

Standard deviations and simple correlations among the fat depot and total fat percentages in the side. Overall correlations (ignoring groups) are above the diagonal and pooled within group correlations below it

	Intermuscular fat	Subcutaneous fat	KKCF	Cod fat	Total fat
SD: pooled within groups	1.76	1.62	1.10	0.24	3.87
overall	2.37	2.14	1.43	0.27	5.22
Intermuscular fat		0.723	0.572	0.629	0.938
Subcutaneous fat	0.699		0.308	0.651	0.855
KKCF	0.454	0.310		0.455	0.683
Cod fat	0.572	0.548	0.449		0.728
Total fat	0.928	0.858	0.648	0.680	

TABLE 3

Residual standard deviations and regression equations for the prediction of percentage intermuscular fat and percentage total fat in the side from percentage subcutaneous fat, and a comparison of predicted with actual means

Group	Prediction of intermuscular fat				Prediction of total fat			
	RSD	Intercept a	Coefficient b	Predicted† - actual	RSD	Intercept a	coefficient b	Predicted† - actual
1 Ayrshire (I)	0.93	10.42	0.54	-1.6	2.63	15.31	1.86	-3.6
2 Angus x F (SI)	1.19	5.08	1.06	-0.8	1.39	7.90	2.50	-1.7
3 Hereford x F (I)	0.78	5.36	0.76	+1.5	1.55	7.99	1.97	+2.8
4 Friesian (I)	0.69	5.90	0.96	-0.3	1.72	8.20	2.30	-0.1
5 Limousin x F (I)	0.85	3.89	1.07	+0.9	1.33	8.00	2.09	+1.6
6 Charolais x F (I)	1.35	6.41	0.88	-0.5	1.61	8.86	2.19	+0.1
7 Hereford x F (SI)	0.92	6.49	0.71	+0.7	1.58	8.90	2.01	+1.3
8 Simmental x F (I)	1.40	6.14	0.88	-0.3	1.68	8.01	2.32	0.0
9 Angus x	0.98	9.54	0.56	0.0	1.72	14.30	1.68	+0.7
10 Friesian (SI)	1.22	5.46	1.01	-0.5	2.45	7.40	2.58	-1.2
11 Welsh Black x	1.20	6.59	0.50	+1.9	1.85	9.70	1.72	+2.4
12 F x Ayrshire (SI)	1.08	11.20	0.46	-2.0	2.61	15.79	1.87	-4.3
13 S. Devon x F (SI)	1.17	6.62	0.91	-0.9	1.62	9.27	2.40	-1.8
14 Simmental x Ayrshire	0.96	6.41	1.05	-1.8	2.22	11.28	2.35	-3.5
15 Simmental x F (SI)	0.95	6.14	0.89	-0.3	1.88	10.07	2.09	-0.5
Pooled within groups: individual lines	1.18	-	-	-	1.91	-	-	-
common slope	1.21	-	0.81	-	1.99	-	2.11	-
Overall (ignoring groups)	1.63	6.45	0.80	±0.9 ‡	2.71	9.62	2.09	±1.7 ‡
F ratio for significance of differences between intercepts/slopes		39.24***	2.99***			45.73***	2.04*	

† Predicted mean (obtained using the overall regression equation) minus the actual mean

‡ Average difference between predicted and actual means

from the actual means for the groups (comparable with the figures in Table 3) being ± 0.5% for both intermuscular fat and total fat.

Discussion

The results support the findings of other workers that dairy-type cattle tend to deposit a higher proportion of their total fat as KKCF and intermuscular fat and a lower proportion subcutaneously than beef-type cattle. Compared within feeding system, the results of the Ayrshire and Ayrshire cross groups occupied a position at the dairy end of the spectrum while the results of Friesian crosses with Angus, Hereford and Limousin sires were at the beef end.

The variation in fat distribution between the groups was reflected in substantial bias for some groups when a common regression line was used to predict the percentage of either intermuscular fat or total fat in the carcass from percentage subcutaneous fat. Although it is not necessarily correct to assume that the bias resulting by prediction from subcutaneous fat percentage would also result in the same circumstances by prediction from measurements of subcutaneous fat (for example, fat areas or depths), it seems intuitively to be a reasonable assumption. If it is the case, then it is clearly important to obtain prediction equations for different breed types or at least make some adjustments when using such measurements. It is worthwhile emphasising that one does not have to actually calculate and apply a common regression equation to occasion a bias; by assuming that the ranking and the relative differences in total fat between breed types are the same as for the fat depths, areas etc., one is effectively applying the equation.

KKCF alone was shown to be a very imprecise predictor of total fat content both within and between breed-type groups. Butterfield (1965) questioned the use of kidney fat for predicting breed differences but suggested that it should prove useful within breed. The results of the present study and those of Martin, Fredeen, Weiss and Newman (1969) and Adams, Garrett and Elings (1973) indicate that this would not be the case.

Although KKCF was poorly correlated with other depots, there was a tendency between breeds for a high carcass KKCF content to be associated with a high intermuscular fat content and *vice versa*. The addition of KKCF percentage to subcutaneous fat percentage, therefore, increased the precision and reduced the bias associated with the prediction of percentage intermuscular fat from the common regression equation. This result supports the findings of Pomeroy and Williams (1974) and indicates that a measurement of KKCF may well be a useful predictor to use with measures of subcutaneous fat particularly when comparing beef and dairy-type cattle. On the basis of their results, Pomeroy and Williams argued that an assessment of KKCF development should be used in addition to the subcutaneous fat score in the MLC Beef Classification Scheme to improve the accuracy of predicting carcass composition. While on the basis of the results alone this would seem sensible, there are other considerations in practice. The scheme does include a subjective conformation assessment which to some extent differentiates between beef and dairy-type cattle. Further, it would probably be necessary in practice to use a subjective assessment of KKCF and not KKCF weight. Results of unpublished analyses carried out on the sample of carcasses included in the present study indicate that the benefits from using a subjective KKCF score in this way are substantially less than those obtained from the use of depot weights.

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NOTE ON THE VALUE OF SUBCUTANEOUS FAT SCORE, AND INDIVIDUAL MUSCLE AND FAT THICKNESS MEASUREMENTS TAKEN ON THE CUT SURFACES AT THE 10th AND 13th RIB AS PREDICTORS OF BEEF CARCASS COMPOSITION

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Abstract

In a study on some 400 carcasses of mixed types, the value of several simple subjective and objective techniques for estimating carcass composition were assessed. A subjective score for subcutaneous fat provided a more precise prediction of tissue percentages in the carcass than any of the individual muscle or fat thickness measurements. Of the fat thickness measurements taken, the one taken over B gave the most precise prediction.

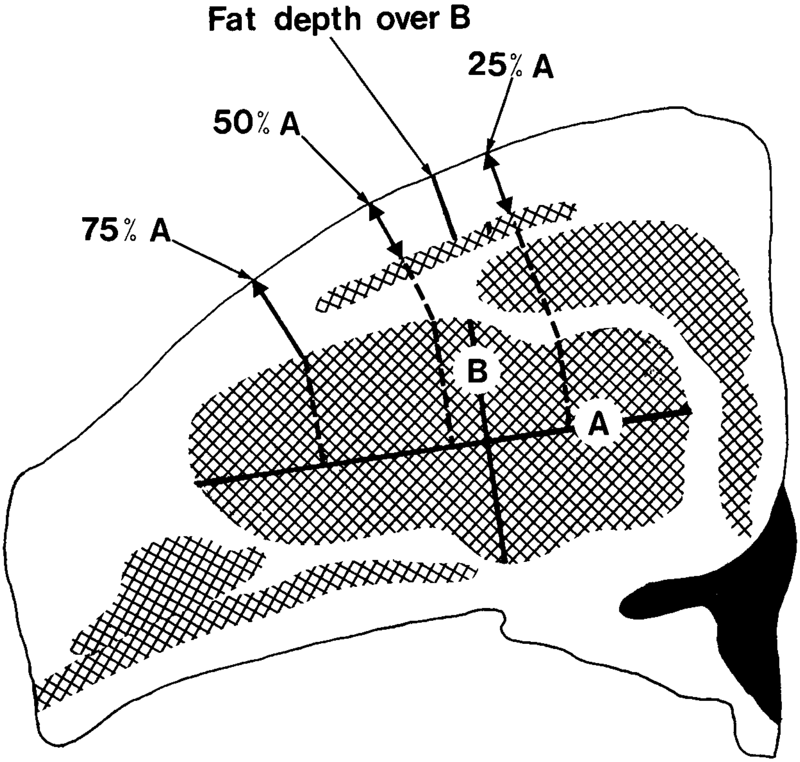
Note

Carcass data for 387 cattle of various breed types and predominantly steers were analysed to compare subcutaneous fat score and muscle and fat thickness measurements as predictors of tissue percentages in the side. The variates analysed and their means and standard deviations are shown in Table 1.

Residual standard deviations for the prediction of the percentages of lean, subcutaneous fat and intermuscular fat in the side are shown in Table 2. The effect of differences in side weight has been eliminated. The results have two notable features:

(1) subcutaneous fat score gave a more precise prediction of tissue percentages than any of the individual muscle or fat thickness measurements,

(2) fat thickness measured over B gave a more precise prediction than any of the fat measurements defined by the subdivision of A.



DEFINITION OF MEASUREMENTS TAKEN ON THE CUT SURFACE AT THE 10th RIB

Table 1 Means and standard deviations of variates analysed

	Mean	SD
% lean) in side	62.2	4.3
% subcutaneous fat) ex KKCF	7.6	2.8
% intermuscular fat)	12.5	2.7
Side weight ex KKCF (kg)	111.4	15.6
Subcutaneous fat score†	2.51	1.35
<u>Measurements at 10th rib:</u> ‡		
Fat thickness at 25% of A (mm)	8.38	6.19
50% of A (mm)	8.49	7.31
75% of A (mm)	9.93	7.00
Fat thickness over B (mm)	8.59	5.76
L. dorsi width A (mm)	123.0	9.3
depth B (mm)	60.4	7.7
area (cm^2)	61.9	7.7
<u>Measurements at 13th rib:</u>		
Fat thickness at 25% of A (mm)	9.65	8.83
50% of A (mm)	5.96	7.45
75% of A (mm)	5.77	5.82
Fat thickness over B (mm)	6.80	4.79
L. dorsi width A (mm)	131.8	9.3
depth B (mm)	64.6	7.1
area (cm^2)	64.9	7.3

† Visual judgement of external fatness on a 7 point scale ranging from 1 (lean) to 7 (fat).

‡ See attached Diagram.

Table 2 Residual standard deviations for the prediction of tissue percentages in the side

	% lean	% sub. fat	% inter. fat
Standard deviation	4.33	2.80	2.65
Subcutaneous fat score	2.88	1.46	2.01
10th rib:			
Fat at 25% of A	3.72	2.28	2.34
50% of A	3.88	2.43	2.44
75% of A	3.83	2.39	2.40
Fat over B	3.32	1.99	2.14
L. dorsi width A	4.20	2.74	2.58
depth B	4.26	2.78	2.64
area	4.03	2.68	2.55
13th rib:			
Fat at 25% of A	4.06	2.55	2.50
50% of A	4.11	2.61	2.53
75% of A	3.97	2.48	2.45
Fat over B	3.12	1.81	2.04
L. dorsi width A	3.87	2.55	2.37
depth B	4.13	2.73	2.58
area	3.94	2.67	2.52

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PREDICTION OF CHEMICAL CARCASS COMPOSITION FROM SAMPLE JOINTS

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ABSTRACT

As direct measurement of carcass chemical composition of cattle is very expensive, it is necessary to consider indirect methods of prediction.

Several methods have been envisaged, using the chemical composition of a rib joint, or various other predictors.

Analyses of the variability of carcass composition have shown that it was related primarily to carcass weight, and that the most variable component was chemical fat. Thus it is possible to estimate carcass chemical composition from carcass weight and a fatness index.

The accuracy of estimation by the various methods used is generally good. The residual coefficient of variation is lower than 9 % for fat ; approximately 5 % for protein or energy. This accuracy is discussed in comparison with slaughter techniques.

The use of such indirect estimation is limited by the effect of various factors affecting the equations (breed, sex), but it is possible to overcome this difficulty by using simultaneously the slaughter technique on some animals, and an indirect method on the whole population.

Indirect estimation of chemical composition could be easily extented to the whole body.

The choice of predictors can be guided by a simple rule : they must be closely related to fatness, accurately measurable and easily obtainable. We consider that carcass weight must be the primary predictor . The others could be the weight of anatomical or chemical components of a rib cut, which is generaly easily obtainable in commercial dressing of carcasses in Europe.

INTRODUCTION

Measurement of carcass composition in terms of tissue weight (fat tissue, muscle, bone)is necessary for studies on growth and development, but to study efficiency of transformation of food into protein and energy, it is also necessary to determine the chemical composition of the carcass. Mincing and chemical analysis of the whole carcass are certainly the best methods, but are very expensive. Thus indirect methods of appreciation, sufficiently cheap to be applied to a large number of animals are necessary.

During the last 30 years, several methods have been published on this subject. The first method proposed (HOPPER, 1944 ; HANKINS and HOWE, 1946) was founded on chemical analysis of a sample joint. The chemical fat percentage in the 9-10-11th rib was highly correlated with the chemical fat in the whole carcass. Later, other methods have been developed with various predictors such as chemical fat in a sample of the edible portion of the 9-10-11th rib cut (KENNICK and ENGLAND, 1960), chemical composition of meat sawdust (VANCE et al, 1971 ; WILLIAMS et al, 1974), subcutaneous fat depth (POWELL and HUFFMAN, 1973 ; CROUSE and DIKEMAN, 1974), weight of kidney fat (POWELL and HUFFMAN, 1973) or weight of tissues in the 11th rib cut (ROBELIN and GEAY, 1975, b). In the various proposed methods, each predictor has been used alone or simultaneously with others. A number of calculations were made with variates expressed as weightsor as percentages. These methods were established on various type of animals(steers, heifers, cows,young bulls) and they concerned either the whole carcass, or only the soft part of it (muscle + fat deposits). Thus it is very difficult to synthesize these results in a simple manner. We shall analyse from a general point of view the different relationships involved in indirect estimation of carcass chemical composition in order to discuss the merits of such prediction.

We have used the residual coefficient of variation (standard error of regression expressed as the percentage of the mean of the dependent variate) as an index of the "closeness" of the relationships. It is a better index than the correlation coefficient which is influenced by the extent to which the data vary.

Table 1

VARIABILITY OF THE WEIGHT OF CHEMICAL COMPONENTS AND THE CALORIFIC VALUE

OF THE CARCASS OF YOUNG BULLS

(ROBELIN et GEAY, 1975, a) (1)

Dependent variates	Fat	Water	Ash	Protein	Energy
R C V (%) at same carcass weight (1)	15.20	2.12	7.46	4.53	7.23
R C V (%) at same carcass weight and same weight of fat (2)	X	1.17	7.46	3.04	2.55

(1) These values have been computed from the results of dissection and chemical analysis of 80 bull carcasses

(2) R C V = residual coefficient of variation (residual standard error of the regression expressed as percent of the dependent variate)

Table 2

RELATIONSHIP BETWEEN INDEX OF FATNESS AND CHEMICAL COMPOSITION OF THE CARCASS

Authors	Animals	Index of fatness	R^2 (1)		
			Water	Fat	Protein
HANKINS et HOWE (1946)	84 steers 36 heifers	Chemical fat % in a ribjoint	0.98	0.86	0.86
VANCE et al. (1971)	8 steers 8 heifers	Subcutaneous fat depth	0.36	0.38	0.31
POWELL et HUFFMAN (1973)	41 steers	Subcutaneous fat	0.74	0.74	0.39
	41 steers	depth kidney fat	0.68	0.67	0.38
CROUSE et DIKEMAN (1974)	27 steers	Subcutaneous fat depth	0.76	0.74	0.72
	27 steers	Chemical fat % in a rib joint	0.83	0.88	0.88

(1) R^2 is the square of the correlation coefficient (variance accounted for) between the percentage composition of the carcass and the predictor of fatness

Table 3 ACCURACY OF PREDICTION OF CARCASS CHEMICAL COMPOSITION (1)

Authors	Animals	Predictors	Residual coefficient of variation (%)		
			Water	Fat	Protein
HOPPER (1944)	3 cows 86 steers	Chemical fat % in a rib joint	-	10.0	-
HANKINS and HOWE (1946)	84 steers 36 heifers	Chemical fat % in a rib joint	-	9.9	-
POWELL and HUFFMAN (1973)	41 steers	Carcass weight. Fat depth. Kidney fat, eye muscle area.	5.2	9.9	8.5
CROUSE and DIKEMAN (1974)	27 bulls	Chemical fat % and protein % in a rib joint. Retail yield. Fat depth. Carcass weight.	2.7	3.8	1.7
ROBELIN and GEAY (1975, a)	80 young bulls	Weight of dissectable fat and muscle in a rib joint. Carcass weight.	1.8	9.1	4.9

(1) Accuracy was expressed as the residual coefficient of variation (residual standard error of regression % of the mean of dependent variate)

RELATIONSHIP BETWEEN CARCASS WEIGHT AND WEIGHT OF CHEMICAL COMPONENTS

The weight of chemical components (water, chemical fat, ash and protein) and the calorific value are very closely related to carcass weight by an allometric relationship. For example, we have found (ROBELIN and GEAY, 1975, b) that the residual coefficient of variation was 15.2 % for chemical fat, 2.1 % for water, 7.5 % for ash, 4.5 % for protein and 7.2 % for energy (table 1).

Fat content is the most variable, and the proportions of the other components are greatly dependent on it : the correlation between chemical fat % and water % of the carcass reaches 0.99 (CALLOW, 1947 ; PRESTON, 1974). From the work of MOULTON and colleagues, it is established that the chemical composition of the lean body mass (carcass weight - fat weight) is practicaly constant. Thus, when chemical fat weight is known exactly, the residual coefficient of variation becomes smaller : 1.2 % for water, 7.4 % for ash, 3.0 % for protein and 2.5 % for energy (table 1). It is now clear that the chemical composition of the carcass depends mainly on fat content, and therefore could be accurately estimated from a good predictor of fatness. Some results from this field of work are summarized in table 2.

METHODS OF ESTIMATION OF THE CHEMICAL COMPOSITION OF THE CARCASS

In the first methods employed (HOPPER, 1944 ; HANKINS and HOWE, 1946), the independent variate (estimated component) was only the percentage chemical composition of a rib joint. The residual coefficient of variation was approximately 10 % for fat (table 3). With several predictors (such as carcass weight, depth of subcutaneous fat, retail yield...). POWELL and HUFFMAN (1973) obtained approximately the same accuracy. With several variates (comprising rib compositional data). CROUSE and DIKEMAN (1974) and ROBELIN and GEAY (1975 b) obtained a greater accuracy (3.8 and 9.1 % respectively for fat) (table 3). The estimation of water and protein was more accurate (1.8-2.7 % and 1.7-3.8 % respectively), that of energy was intermediate (4.9 %). The very good fit of CROUSE and DIKEMAN'S equations is certainly due to the fact that they were also only concerned with the soft parts of the carcass (muscle + fat deposits).

We have observed that the weights of chemical components of the 11th rib did not give a better estimate than the weights of muscle and fat deposits of the rib. This is explained by the good relationship between physically separated fat in the rib and fat deposits in the carcass (ROBELIN et al,1975b), and by the good relationship between anatomical and chemical composition of the carcass (HOPPER, 1944 ; HANKINS and HOWE, 1946 ; VANCE et al, 1974 ; ROBELIN and GEAY, 1975, b).

From the results of VANCE et al (1971), rib meat sawdust ether extract would be a very good predictor of chemical fat percentage in the carcass (computed residual coefficient of variation for fat equals 5 %). In these results, this predictor appeared better than the weight of physically separable fat in the carcass (RCV = 8 %), which is not easily explicable.

Summarizing, it is possible to estimate carcass chemical composition from carcass weight and a good predictor of fatness (chemically or physically separable fat in a rib joint, fat depth, weight of kidney fat, meat sawdust ether extract...). We can reasonably assume that accuracy (residual coefficient of variation) would be approximately 10 % for fat and about 5 % for energy or protein.

As a first approach, it is possible to calculate the calorific value of the carcass from weights of chemical fat and protein ; we have obtained a very close relationship on 80 carcasses :

$$\text{Energy (Mcal)} = 9{,}367 \times \text{Fat (kg)} + 5{,}478 \text{ Protein (kg)}$$

The residual coefficient of variation is 2.25 %, indicating that the calorific value of fat and protein are relatively constant. The coefficients of the relationships (9.367 and 5.478) are very close to those given by REID et al (1968), 9.499 and 5.447 for the calorific values of fat and protein respectively.

DISCUSSION OF THE USE OF THIS METHOD

In order to simplify this discussion, we shall discuss primarily fat estimation which is perhaps the most interesting. Three major points must be discussed : the accuracy of the estimation compared with direct methods after slaughter, the constancy of the relationship and the possible extension of the method. Lastly we shall try to choose different predictors of carcass chemical composition.

Accuracy of the estimation

The residual coefficient of variation of fat estimation reaches approximately 9 %. We shall try to evaluate this indirect method of appreciation in a practical situation. What is the number of animals necessary to show differences (in fat content) between two groups of animals with the same carcass weight, when measuring chemical composition by analysis or by indirect estimation ? Suppose that we want to show a difference only when it is greater than 10 % of the mean weight of fat in the animals. This least significant difference (LSD) is related to the number (N) of animals per group, and the variance of the difference (γ) by the relationship :

$$LSD = t_{0.05} \sqrt{\frac{\gamma}{N}}$$

where $t_{0.05}$ is the student t value (approximately 2)

$$N = \left(\frac{t_{0.05}}{LSD}\right)^2 \times \gamma \simeq \frac{4}{100} \times \gamma = \frac{\gamma}{25}$$

When measuring the chemical composition of a carcass by analysis, we shall find a within group variability of 15 % approximately (variability of fat content at the same carcass weight. table 1). Thus, γ_1 (value of γ expressed as ‰ of the mean weight of fat) will be :

$$\gamma_1 = 2 \times (15)^2 = 450$$

$$N_1 = \frac{450}{25} \simeq 18 \text{ animals per group}$$

When estimating chemical composition by some indirect method, the true variability of fat at the same carcass weight will still remain 15 %, but that observed will be increased by the error of estimation (9 % table 3). γ_2 will then be :

$$\Upsilon_2 = 2 \times (15^2 + 9^2) = 612$$

$$N_2 = \frac{612}{25} \simeq 25 \text{ animals per group}$$

Thus, in this practical situation, we obtain the same "accuracy" with an indirect method on 25 animals, as with the direct one on 18 animals. Since the indirect method costs less, it may be considered preferable.

However, this calculation is founded on the theoretical accuracy of the equation (RCV = 9 %) which in not true in practice. It is assumed in the regression model, that independent variates (predictors) are measured without error. Thus, it would be necessary to increase the value of the RCV and therefore, the ratio between N_2 and N_1, the number of animals per group in each case.

We can conclude that, if the first property of a predictor is to be closely related to the component estimated, the second one is to be accurately measurable.

Constancy of the prediction relationship

It is assumed that the relationship observed on some animals is true for other animals. This proposal is probably correct for animals of the same breed and sex, but it is not certain in other cases. For example, the relationship between carcass weight and weight of chemical component is variable between breeds. At the same carcass weight, early maturing animals are fatter than those maturing later (GEAY and MALTERRE, 1973 ; DIKEMAN and CROUSE, 1975) and when several variates are involved in the relationship (carcass weight, weight of fat and weight of muscle in a rib joint), these differences are not always significant (ROBELIN and GEAY, 1975 a and b). It seems reasonable to assume that increasing the number of independent variates in the equation, reduces the magnitude of the effect of different factors on the coefficients of the estimation equation. However, in no case can the relationship be considered identical for different breeds or sexes. When utilizing equations adapted to the type of animal , it is possible to predict in absolute terms the weight of chemical components. In other cases, these relationships may be used to classify animals according to their composition.

It is certain that the best use of such an indirect method of estimation, is simultaneously with a direct method after slaughter, in the way we have already explained in our report about dilution techniques.

Extension of this indirect method of estimation of chemical composition

Although of importance, this method is limited to the carcass. It would be better to have an estimate of the empty body composition in order to calculate the actual efficiency of energy or protein deposition. GARRET and HINMAN (1969) have proposed a relationship between the composition of the carcass and the empty body, but it would be better to estimate the composition of the fifth quarter, independently of that of the carcass. It would certainlv be easy because it is possible to measure accurately the weight of fat deposits (peritoneal , mesenteric...) which are certainly as in the carcass, the main factor of variation of the composition of this part of the body. We can surely assume that the accuracy would be at least as good as for the carcass. It should be possible to determine the energy content of the empty body with a coefficient of variation of about 5 % which would be a reasonably good accuracy for estimation of energy retention efficiency. In this way we have begun to measure (by mincing and analysis) the composition of the empty body of bulls (50 animals at present) but the chemical analysis is not finished.

Choice of predictors of carcass chemical composition

For studies on growth and development, post-slaughter dissection and chemical analysis of the body components are still the best methods since these techniques are the most accurate and give the widest information on body composition. When chemical composition only is required, it seems that indirect methods could be sufficiently accurate so long as some conditions are satisfied : use of several predictors, accuracy and repeatability of measurement of these predictors, testing the good fit of the relationships on a number of animals.

The predictors must be chosen primarily according to their prediction value (correlation with chemical composition of carcass), and according to the accuracy of their measurement. They must be chosen also according to their ease of measurement. Certainly, the first predictor must be carcass weight. Others could be the weights of anatomical or chemical components of a rib cut as we have used (ROBELIN and GEAY, 1975 a and b). Rib cuts are generally easily separated in the commercial dressing of carcasses in Europe. Subcutaneous fat depth or weight of kidney fat could be very good additional predictors, provided that they are sufficiently standardized. It should be remembered, that the more numerous are the predictors, the more accurate would be the estimation.

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CHEMICAL COMPOSITION OF CARCASSES AND SAMPLE JOINTS : SPECIFIC GRAVITY DETERMINATION

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Abstract

The literature is briefly surveyed and the physical basis and assumptions of the method are emphasised. Since there is little difference between the densities of the most obese and the very thinnest carcass it is necessary to make density measurements with particular precision. The need for adequate temperature control is emphasised and the effect of dehydration is considered.

Variation in the density of individual tissues has not been afforded much attention in the literature yet would appear to be a fundamental factor limiting the accuracy of the densitometric method. The densities of individual tissues are tabulated and related to their chemical compositions.

Introduction

Specific gravity has been used to estimate the composition of a wide range of foodstuffs, from alcoholic beverages on the one hand to milk, and potatoes on the other. It was first suggested as a method of estimating the composition of carcasses in the early 1940's and since then has been used fairly widely on all species of animals reared for meat, cattle, pigs, sheep, as well as for human beings and animals used for physiological experiments. There is therefore a fairly extensive literature which has been reviewed recently by Garrett (1968) and Pearson, et al (1968).

At the time when these surveys were written relatively few papers had been published specifically on cattle, but since then several extensive studies have been made mainly by American workers and this new work will be described in this paper. The paper will be written in two sections: Fact and Theory. The first section is concerned with accuracy of measurement and the density of individual tissues and carcasses and abstracts briefly the results of some of the more recently published studies. In the second shorter section, Theory, the rationale of the method will be examined to try to explain discrepancies in the prediction equations given by different authors.

FACT

Definitions

The specific gravity ($d_{t_1}^{t_2}$) of any substance is the ratio of the mass of a certain volume of the substance at the temperature t_2 to that of the same volume of reference substance (usually water) at temperature t_1 (International Critical Tables, 1926) whereas the density of a substance is its mass per unit volume.

Therefore the density of a carcass depends on the temperature of the tissue only whereas its specific gravity will depend on the temperature of the tissue and the temperature of the water to which it is referred.

Accuracy of measurement

Since there is very little difference between the densities of the most obese and the very thinnest carcass it is necessary to make measurements with particular precision in order to discriminate between carcasses differing in fatness by 1 or 2 percentage points. For example an uncertainty in density of only .001 g cm^{-3} corresponds to a perturbation in predicted fatness of .2 to .8% points. Clearly density has to be measured to about 10^{-3}g cm^{-3} to ensure that uncertainties in measurement alone do not contribute significantly to the scatter of the relation between density and composition. Particular care is necessary in taking measurements, for example in temperature control, and ensuring that there are no air bubbles trapped at the surface of the carcass. In subsequent sections some of these factors will be considered in more detail. Small variations in the densities of the individual tissues are also important and this will also be considered below.

Temperature

Published studies of the relation between the density and composition of carcasses seem to be limited to fresh as opposed to frozen material. This is not surprising since the small difference between the density of fresh fatty tissue and muscle will be reduced further by freezing. Recent work by Kent (1975) has shown that there is a gradual accretion of ice in frozen muscle during storage, which implies a gradual reduction in density with time. Thus, the density of a frozen carcass is likely to depend on storage/temperature history as well as composition.

When the method of weighing in water has been used, corrections have sometimes been applied to allow for the expansivity of water, but this is small compared with the expansivity of the soft tissues themselves (Mendez & Keys 1960, Mendez et al 1960, Jarvis 1971)and this is often neglected. Jarvis 1971 found that the thermal coefficient of expansion of muscle was about twice that of water over the temperature range 5-30°C (3.75×10^{-4} °C^{-1} compared with 1.7×10^{-4}°C^{-1} for water). That of fatty tissue was about nine times (15.3×10^{-4} °C^{-1}). Thermal effects are therefore more important in fat carcasses than in lean ones. The expansivity of a very obese carcass might be 10^{-3}°C^{-1} which corresponds to differences in the predicted level of fat of .2 to .8% points per °C.

Behnke (1968) considered that thermal effects could be responsible for the large variations in the slopes and intercepts of published relations between the density and composition of carcasses and Garrett, (1968) thought that these differences were unlikely to be physiological in origin.

Presumably thermal contraction during chilling was responsible for the considerable increase in the specific gravity of pig carcasses recorded by Kline, Ashton and Kasterlic 1955, when they measured at intervals during refrigeration 40 pig carcasses (200 lb live weight). They measured specific gravities of .9965, 1.0214, 1.0249, 1.0276 immediately after slaughter and at 24 hours, 48 hours and 72 hours respectively. They concluded that it was necessary to standardise the time after slaughter when relating the specific gravity of carcasses to their compositions.

Their work has been widely quoted and, at least in recent times, standardisation of the chilling times in a given experiment has been common-place.

Unfortunately in the Kline,Ashton & Kasterlic publication, which is an abstract only, neither the chilling conditions used nor the internal temperature of the carcasses are quoted. Clearly the time for temperature equilibration will depend on the chilling conditions, air temperature, velocity and humidity and on the mass and fatness of the carcasses. Longer times will be required for cattle than for pigs. Bailey and Cox (in preparation) calculate that the deep leg temperature in a 100 kg beef side chilled in air at 0°C with a speed of 1 m/s will reach 1°C in just under 48 hours whereas under identical conditions a 260 kg side will take 88 hours. Chilling procedures and conditions prevailing in the UK and other EEC countries are very variable. For example, Malton (1972) in a survey of beef chilling in the UK found the deep temperature of one beef carcass reached 4°C in 31 hours whereas another took 114 hours to attain the same temperature.

Dehydration

As carcasses cool they also lose water, the amount depending on several factors including air temperature, velocity, relative humidity, the mass of the carcass and its fatness. It is interesting to estimate the effect of dehydration on density since the amount of water lost during chilling and storage will vary and could contribute to some of the unexplained variance in density. No experiments seem to have been performed to find out how density is related to dehydration and one must resort to calculation.

If the density of carcass water is taken as the same as that of free water, the effect on density of dehydration is roughly 5×10^{-4} g cm^{-3}/% water loss. Therefore perturbations in density due to differences in evaporative loss, though appreciable are likely to be small.

Densities of carcass tissues

The densities of individual tissues are not constant, bone being particularly variable. Fursey (1975) measured about 1000 bovine limb bones excised from 110 carcasses of 4 breeds ranging in age from 6 to 36 months and found that the density of individual bones ranged from 1.24 to 1.71 g cm^{-3}. Much of this variation was due to differences between the various bone types within a limb. For example metacarpal and metatarsal bones were more dense than either the humerus or femur. In general, the older the animal the more dense were its bones and there were differences in the densities of bones taken from animals of the same age but different breed. Unfortunately the composition of the bones was not measured but there can be little doubt that much of the variation was due to difference in composition.

Field, et al (1974) measured the composition of whole lumbar and cervical vertebrae, ribs and femurs from 14 bovine carcasses ranging in age from 2 to 96 months and found substantial changes in composition with age. Basically the effect was a gradual dehydration and an increase in fat and ash. The overall trend in composition conforms with an increase in density with age.

Although much less striking in magnitude the differences that exist in the densities of individual soft tissues are important (Table 1). The difference between intermuscular and subcutaneous fatty tissue reflects the much higher fat content of the subcutaneous depots. There is relatively little scatter in the density of muscles (Table 1).

In formulating a relation between the density and composition of carcasses

Table 1. Density and composition of beef tissues (± Standard deviations)

Tissue	n	% fat	% water	Temperature °C	Density g cm^{-3}	Reference (if not this work)
MUSCLE						
Longissimus dorsi (LD)	6	2.7 ± .7	74.1 ± .8	3	1.074 ± .003	
"	50	3.3	73.7	3	1.069	Bieber *et al*, 1961
Semitendinosus (ST)	12	1.6 ± .4	75.0 ± .45	2	1.074 ± .002	
"	50	-	-	-	1.073 [a]	Kline *et al*, 1969
Biceps femoris	50	-	-	-	1.069 [a]	"
Semimembranosus	50	-	-	-	1.070 [a]	"
Adductor	50	-	-	-	1.072 [a]	"
Quadriceps femoris	50	-	-	-	1.064 [a]	"
FATTY TISSUE (from round joint)						
Intermuscular	12	64.0 ± 5.1	26.8 ± 3.6	2	1.006 ± .005	
Subcutaneous	13	78.8 ± 6.5	14.0 ± 3.6	2	.97 ± .02	
MUSCLE/FATTY TISSUE MIXTURES						
Arm and heel cut	18	19.0	62.0	3	1.041	Bieber *et al*, 1961
IM+SC+LD+ST [b]	43	43.0	42.5	3	1.021	
HIDE	20	4.3 ± 4.2	65.8 ± 3.0	20	1.09 ± .02	
BONE						
hind cannon (6 month	-	-	-	20	1.43	Fursey, 1975
hind cannon (24 "	-	-	-	"	1.64	"
fermur (6 month	-	-	-	"	1.26	"
fermur (24 month	-	-	-	"	1.37	"
FAT						
subcutaneous	4	100	-	37	.9000	Fidanza *et al*, 1953
Internal	4	100	-	37	.9076	"
-	-	100	-	Measured at 25°C corrected to 3°C	.9122	Bieber *et al*, 1961
BONE MINERAL						
Tibia (96.3% ash)	2	0	0	36	3.00	Mendez and Keys, 1960

[a] specific gravity. [b] calculated values. RSD in $\frac{1}{\rho}$ was .012cm^{3}g^{-1} after allowing for linear dependence on fatness

it has sometimes been assumed that the densities of the individual tissues are themselves constants. This, clearly, is not true although the variations are in part explicable in terms of variations in chemical composition.

Mixtures

Whitehead (1970) described an instrument, developed by the Honeywell Company, to measure the specific gravity and thereby the fatness of 750g samples of chopped or comminuted meat. An accuracy (RSD) of ± 1.5% points fat was claimed. Comparable precision was quoted by Hansen (1971) for a similar instrument developed at The Danish Meat Research Institute for measuring the fat content of meat trimmings. The instrument was designed to work on the production line and was calibrated both for fresh and cured meat. In contrast Busch (1974), in a study of the specific gravities and fatness of 40 beef shoulders and 82 comminuted samples of beef, concluded that the specific gravity method was not sufficiently accurate for the routine estimation of fatness.

The density of carcasses

Until recent times there was little published concerning the relation between the density of bovine carcasses and their composition. Table 2 summarises results obtained since Garrett's (1968) review.

In agreement with the early work of Kraybill et al (1952) high correlations between specific gravity and composition have since been reported by Garrett and Hinman (1969) and Preston et al 1974, both studies recording residual standard deviation of about 2% in fat. While the animals examined by Preston et al 1974 were specially selected to exhibit a wide range in bone content (11.7 to 18.6% of carcass weight separable bone) their findings contrast with those of Waldman et al 1969 who found poor correlation when they studied 14 calf carcasses ranging from birth to 227 kg live weight.

Disappointing correlations were also reported by Kelley et al 1968 who related to specific gravities of 156 steer carcasses to the chemical composition of the edible portion of the carcass. The animals differed widely in age and were fed on different planes of nutrition. A fairly high correlation was obtained in the fat range 20 to 30%, but when the fat level was less than 20% the correlation was poor.

Gil et al 1970 measured the density and composition of the quarter carcasses of 18 Herefords ranging from 5 to 18 months of age. Their overall residual standard deviation of 4.1% fat was much higher than reported by others. When the data was divided into groups on the basis of fatness specific volume was significantly correlated with water and protein in the high fat groups only, 30-42% fat, whereas significant relations were obtained with % ash for all the groups except those with the very lowest fat.

Sample joints

A few studies have been made of the relation between the specific gravity of sample joints and the composition of the whole carcass. Kelley et al 1968 examined ten wholesale joints, finding that, of these, the specific gravity of the 9-10-11th ribcut was the best predictor of fatness. Kraybill et al 1952 also reported high correlation between the specific gravity of this cut and the specific gravity of the carcass and empty body. The relation between the specific gravity of joints and that of the whole beef side was examined in

Table 2 Specific gravity and composition of beef carcasses

Temperature °C Water	Meat	Specific gravity	% Fat	% Protein	% water	% ash	n	Reference
7	6	1.068	23.4	16.7	54.9	4.5	8	Preston et al 1974
"	"	1.068	22.3	17.1	55.8	4.6	12	"
"	"	1.047	33.9	14.8	47.0	4.0	16	"
2-4	-	1.060	24.0	18.9	-	-	3	Powell and Huffman, 1968
"	"	1.053	31.6	16.1	-	-	3	"
"	"	1.041	36.1	15.1	-	-	3	"
"	"	1.038	41.6	13.3	-	-	3	"
"	"	1.034	45.1	12.9	-	-	3	"
corrected to 4°C	-	1.056	27.9	15.9[c]	52.3	4.2	48	Garrett and Hinman, 1969
3	3(?)	1.088	12.4	18.5	65.1	4.0	11[d]	Gil et al, 1970
"	"	1.072	17.2	17.8	62.0	3.1	14[d]	"
"	"	1.067	22.4	17.1	57.5	3.0	14[d]	"
"	"	1.068	27.8	16.2	53.1	2.9	6[d]	"
"	"	1.057	31.7	15.3	50.2	2.9	6[d]	"
"	"	1.051	38.9	13.7	44.5	2.8	8[d]	"
4	4	1.079[a]	4.8	17.2	-	27.0[b]	5	Waldman, et al, 1969
4	4	1.073[a]	6.8	18.0	-	23.8[b]	10	"
4	4	1.080[a]	15.3	17.8	-	20.0[b]	21	"
-	-	1.096	(5.5)	(19.3)	(73.2)	26.3[b]	38	Kelley et al, 1968
-	-	1.082	(15.1)	(17.9)	(65.5)	20.5[b]	57	"
-	-	1.068	(24.9)	(16.3)	(57.7)	17.8[b]	33	"
-	-	1.047	(35.5)	(13.9)	(49.6)	14.3[b]	20	"
-	-	1.032	(44.8)	(11.6)	(42.6)	12.1[b]	5	"

a Specific gravity measurements on some carcasses only

b denotes % separable bone

c Nitrogen quoted, and converted to protein by multiplying by 6.25

d quarter carcasses

( ) Figures in parenthesis denote chemical composition of carcasses after bone removed.

detail by Ledger et al 1973 who found curvilinear relationships for some joints. They found a high linear correlation (r = .94, RSD = .006) between the side and the 10th rib cut which also correlated well with the % separable fatty tissue in the side (r = .96, RSD = 2.3%).

THEORY

A mathematical justification for the relation between carcass density and composition was first given by Morales et al 1945, who by making various assumptions concerning the relative masses of the muscle, skin, nervous tissue and bone and by assuming that the densities of the individual tissue components were constant derived an expression of the form:

$$x_n = \frac{A}{\rho} + B \qquad (1)$$

where A and B are constants x_n is the proportion of fat and ρ is the density of the body. The analysis is slightly confusing since it fails to distinguish clearly between fat and fatty tissue. Using different assumptions Keys & Brozek 1953 and Brozek et al 1963 derived a relation of the same form as equation (1) for the bodies of mature human beings. For the purpose of this analysis they considered the body to be composed of different proportions of two types of tissue a reference body and obesity tissue, the composition of the latter depending on whether by adjustment of the diet, the body was gaining or losing mass. This affected A and B by about 10% only and the values they derived (which incidentally they quote to 4 significant digits) differ only slightly from the values originally proposed by Morales et al 1945.

In contrast actual measurements of A and B for meat animals vary widely, the maximum reported A being some three times larger than the minimum. In order to assess why A and B vary by so much it is useful to look at the assumption of Keys & Brozek et al in more detail.

Let the composition of a carcass be represented by the column vector

$$[x] = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}$$

We may write

$$[x] = k[m] + [c] \qquad (2)$$

if the carcass can be considered to be made up of a mixture of two types of tissue, a reference body and obesity tissue, and k is a real number $0 \leqslant k \leqslant 1$ and $[m]$ and $[c]$ are column vectors constrained by the following relations:

$$\sum x_i = 1$$

$$\sum m_i = 0$$

$$\sum c_i = 1$$

If the mass fraction of the i^{th} component is zero when k = 0 then

$$c_i = 0$$

and if the mass fraction of the j^{th} component is zero when k = 1 then

$$c_j = -m_j$$

If we now assume that the volumes of the n individual components are additive

$$\frac{1}{\rho} = \sum \frac{km_r + c_r}{\rho_r} = \frac{x_n - c_n}{m_n} \sum \frac{m_r}{\rho_r} + \sum \frac{c_r}{\rho_r}$$

i.e. equation (1) holds if ρr is constant

and $A = \dfrac{m_n}{\sum \frac{m_r}{\rho_r}}$ and $B = -A \sum \dfrac{c_r}{\rho_r} + c_n$

we may choose to make $c_n = o$ by defining k = o when $x_n = o$.

If equation 3 does not hold but there exists a curvilinear relation between the components,

$$x_r = x_r \ (k)$$

there is a curvilinear relation between $\frac{1}{\rho}$ and x_n :

$$x_n = x_n \ (\frac{1}{\rho})$$

Finally, the existence of a relation of the form of equation (1) does not itself imply that the assumptions used to derive it are valid. If equation (2) holds equation (1) merely implies that ρ_r and x_r are such functions of x_n that

$$\frac{1}{A} = \sum^{N} \frac{1}{\rho_r}\left[\frac{dx_r}{dx_n} - \frac{x_r}{\rho_r}\frac{d\rho_r}{dx_n}\right]$$

$$\sum \frac{d^2}{dx_n^2}\left(\frac{x_r}{\rho_r}\right) = 0$$

As the major components other than fat in the body of animals have densities near or greater than unity one would expect the value of $\sum \frac{c_r}{\rho_r}$ to be near but slightly less than one and relatively independent of small changes in ρ_r or c_r, since $c_r \geqslant 0$ and $\sum c_r = 1$. On the other hand the value of $\sum \frac{m_r}{\rho_r}$ will be susceptible to small fluctuation in ρ_r or m_r since it is a summation of positive and negative terms of similar magnitude ($\sum m_r = 0$).

We therefore see that the coefficients A and B may vary widely but there should be a linear relation between them, with slope very near -1. It is not possible by this means to ascertain whether this is caused by fluctuations in ρ_r or m_r and c_r, or in fact whether the fluctuations are merely a reflection of the uncertainties of the least squared fits, but the analysis does serve to show that the technique is very sensitive to small fluctuations in the densities of individual components and to deviations from the assumed relationship between the individual components. Relation (2) does not hold in immature animals (e.g. Moulton, 1923, Dickerson & Widdowson 1960, Widdowson 1968) and deviation from this relation might occur if animals are suffering from a pathological condition or are in some other way abnormal.

CONCLUSIONS

Several studies have shown that the relation between the density and chemical composition of carcasses could be useful when a rapid, if rough, comparison between groups of carcasses is required. This is true provided that the carcasses are from normal healthy and mature animals, there being theoretical objections if the animals are immature.

Density depends on factors other than composition, notably temperature, and failure to standardise these conditions will cause errors and alter the prediction equations.

It is possible to identify two factors which limit the accuracy of the method. The first is that it assumes that there exist exact relationships between the proportions of individual chemical components (e.g. the carcass is composed of a reference body and obesity tissue). It also assumes that the densities of the individual components are constant. The former assumption implies that inaccuracies will be introduced by the scatter of compositions about the assumed locus. These inaccuracies might be reduced by taking more than one physical measurement such that there are as many physical measurements as there are unknowns. In contrast the assumption that the densities of individual chemical components are constant is fundamental to the densitometric approach and it is surprising that relatively little has been published to support this point.

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EEC Seminar on Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments, Zeist, 1975.

DISCUSSION ON SESSION 4 ON "ASSESSMENT OF CARCASS COMPOSITION"
Discussion leader: A. Cuthbertson.

Questions on specific papers

On the paper by W i l l i a m s, *Torreele* suggested that prediction in his experience is improved by the inclusion in the equation of sample joint weight as % total weight of side.

Replying to *Verbeke*, B e r g s t r ö m stated that he had found large variations in the rib joint, possibly in the proportions of individual muscles as a results of rigor and its effect on the position of the muscles. The size of the joint (7 % of the carcass) used in the Belgian work possibly assists its predictive value.

S o r n a y stated that the measurements of carcass length and depth used in his work were those described in the EAAP recommendations.

Tayler asked C u t h b e r t s o n to include in his printed paper his useful graph of costs of predictive methods, but *Williams* pointed out that depreciation of the carcass resulting from the removal of sample joints would be important and would modify the curve.

R o b e l i n replied to *Lanari* that the energy content of fat in his paper was derived from Limousin bulls and was in the form, calories per g fresh material.

General Discussion

The *discussion leader* suggested that a common base-line for comparisons is required, to understand why the same types of assessments give different results in different countries. From this point we must decide which methods are most valuable. Specific gravity was too inaccurate, but chemical analysis was of value in certain nutritional studies.

Robelin: The base-line must be adapted to the aim of the experiment. Combinations of methods might overcome the low accuracy of some when used alone. Breed must be taken into account.

Cuthbertson: The product, in terms of amounts of tissues, is important at the end of many experiments.

Robelin: In nutritional experiments the deposition of energy and protein is of interest.

Kalweit: In such experiments the whole of the body tissues should be analysed.

Williams: Weight and distribution of tissues is also of interest in nutritional experiments.

Carroll: Chemical analysis can be used to avoid tissue separation and the problem that 'lean meat' contains intramuscular fat. A base-line of lean, independent of fat, is required, although fat plus lean is purchased by the consumer.

Béranger: I agree, we need to determine muscle weight. Chemical composition can be predicted from carcass weight combined with an index of fatness, in feeding experiments, However, it is important to relate muscle, fat and bone with market requirements which are muscle plus fat, in each country. How should these two aspects be related to each other?

Cuthbertson: It seems that for breed comparisons, physical separation plus chemical analysis of tissues is required.

Torreele: There are breed differences in the relationship between intra- and inter-muscular fat.

Williams: Anatomical dissection seems the only rational approach, to avoid differences in butchery methods, with the addition of chemical analysis.

Miles: There are big variations in the fat content of fatty tissues.

Robelin: Chemical analysis of the whole body should be included.

Cuthbertson: This would be appropriate in studies of efficiency of energy or protein deposition. When considering physical separation, should the technique be to use a butcher's knife, as at MLC (18 manhours per side, cost £20 in depreciation) or to use a scalpel and scissors? A common base-line must be precise but not too expensive.

Pomeroy: Muscle separations can be carried out with a knife, as by Butterfield. The time-consuming operations are bone cleaning and fat-trimming.

Williams: We use a knife now at MRI. Long bones are readily cleaned but vertebrae could be less thoroughly cleaned to save time. However, tissue separation alone gives no indication of the distribution of lean meat.

Pomeroy: The anatomical approach is universal. Nomenclature has been standardised by a Veterinarian Committee (Nomina Anatomica Veterinaria, 2nd et., Vienna, 1972) and this should be used.

Cuthbertson: Jointing and separation can be combined. The degree of separation and use of chemical analysis could be standardised.

Verbeke: Dissection should be the same whichever method is used, scalpel or knife. There is a loss of important information if full anatomical dissection is not carried out. Sample joint relationships can be made comparable between countries if complete dissection is carried out.

Sornay: Both commercial jointing and anatomical dissection are needed.

Cuthbertson: That is a good summary of the position. What should be done with 'other tissues'? We need clear definitions of procedure e.g. regarding connective tissue.
We should now consider the 'short-cut' (prediction) procedures which can be applied when full separation is not possible. The method will depend on the circumstances.
Pomeroy: The method of evaluation should be planned before the experiment begins, and critically examined.
Harrington: Is a 'standard European sample joint' really a suitable approach? Results should be presented only in terms of the composition of the sample, not a prediction.
Tayler: It is the fatness of the whole carcass which needs to be predicted in many experiments. The application of suitable techniques to experiments can be seen as a pyramid where a relatively small number of comprehensive experiments at the top will have full dissection in association with individual feed recording; larger numbers of animals, possibly group-fed, may be associated with sample joint and other 'short-cut' techniques. These help to relate the results of experiments to commercial practice.
Harrington: I was referring to the danger of using predictions with sample joints which might be from different breeds of cattle.
Harries: It is important that the denominator should be well defined when percentages are presented.
Williams: Anatomical dissection plus prediction equations should show how applicable the data are to other populations of cattle.
Cuthbertson: The stability of prediction from samples over many populations is important. The paper from Italy shows this. A 'stable' joint should be chosen. We should now consider the questions raised by *de Boer*.
Riordan: I am concerned about the large step from a base-line to estimations. Commercial jointing is needed to give commercial value. There is scope for standardised cutting to relate total dissection results to distribution of tissues. Common lines of cutting have been proposed for the feet, some muscles, and lumbar ana sacral vertebrae. More standardisation of cutting the side between the ribs is required, e.g. at the 10th rib, which is acceptable in Germany, France and the United Kingdom.
Williams: The variation between sides is large in jointing methods but the MLC method of using a spirit-level should reduce this.
Cuthbertson: The spirit-level is used on the suspended carcass in conjunction with anatomical reference points, to mark a point on the dorsal line where the

cut is started, e.g. in separating the neck from the shoulder region.

Torreele: Some guidance is required on the methods to be used when there are abnormal numbers of ribs or vertebrae.

Williams: Is there a general view on the desirability of publishing the EAAP survey on methods of jointing and dissection?

De Boer: There seems to be agreement to do that in its present form.

Cuthbertson: To summarise:

1. The method chosen to assess carcass composition will depend on, for example, the resources available, the accuracy required for a particular project, and the commercial cutting procedures operating in each country.

2. A common base-line is valuable. In certain nutritional studies chemical composition is useful, but this should be combined with physical separation whenever possible. In other studies, physical separation using a butcher's knife should provide the base-line combined with chemical analysis of samples of tissues to check on the standard of physical separation. In growth studies individual muscles can be weighed. So far as jointing procedures used prior to separation of tissues are concerned, in some situations standardised commercial cutting lines are appropriate and in others jointing using muscle boundaries as the dividing line may be more suitable. It is quite feasible for commercial jointing to be combined with muscle dissections within joints, since individual muscles occurring in different joints can be added to establish whole muscle weights.

Cutting lines are difficult to standardise but there is some scope to reduce differences. Further consideration is needed of details such as photographic standards.

Sample joints can be used in many situations where full dissection is not possible, but there is the problem of removing joints without incurring heavy loss in value of the carcass.

There is scope for more work on comparisons of the predictive value of as many procedures as possible, both singly and in combinations of all proposed methods.

Part 5

ASSESSMENT OF MEAT CHARACTERISTICS, INCLUDING SAMPLING

EEC Seminar on Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments, Zeist, 1975.

PROBLEMS OF THE MEASUREMENT OF TENDERNESS

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Abstract:

Among the meat characteristics generally measured, tenderness (or toughness) is the most important. But toughness is difficult to define accurately. What physical or mechanical characteristics are really informative and what suitable apparatus to measure them can be proposed ?

The choice of the sample(s) is always a subject of controversy. One muscle (especially Longissimus dorsi) seems insufficient. What can be the right number and which muscles can be chosen to be representative of the whole musculature at different age or carcass weight ?

Many factors can change tenderness and can have an effect on sensory evaluation. For this last aspect a taste panel seems to be the best method of assessment.

During storage conditions, tenderness is affected by the aging process. Elasped time between slaughtering and measuring of toughness is important.

If generally the piece of meat to be measured is cut in the same direction as the muscle fibres, the shape chosen is usually square or round. The first seems more convenient. Owing to the mechanical properties of the meat, thickness and temperature of the piece are important.

In the different countries, meat is not cooked to the same degree, and a method to measure tenderness must be adopted. Besides mechanical measurement it is necessary to measure the most important biological variation in toughness, namely the amount and solubility of collagen.

Introduction

Research on meat tenderness may seem unrealistic to those people in the world who have insufficient protein in their diet...To them, concentration of all efforts on research for increasing meat quantity will certainly be the first aim. But on the other hand, it is not possible to regard consumer satisfaction merely in terms of quantity. Psychologically and physiologically, eating is more than feeding , Hence, our knowledge of how to prevent spoilage and wastage, and how to maintain or eventually improve the organoleptic qualities of human food, must be increased. With the evolution of social conditions,

people like to eat more meat and less vegetable proteins.
Meat-eating has become a status symbol with a long tradition behind it. If presently, for many consumers, traditions have been forgotten, the idea that meat is really an indispensable food has taken hold. In western countries, more consumers require a high level of quality and are willing to pay more for meat than for others sources of protein. They prefer meat with a high lean to fat ratio, meat which is bright red in colour, tender and tasty. The first two characteristics are significant commercially, because they influence the housewife's decision when buying. Flavour and tenderness contribute directly to the consumer's satisfaction. Of, the two, tenderness is the most important because if the meat is too tough, flavour cannot be appreciated. Of the organoleptic characteristics of meat, tenderness is presently the most important in some countries, especially in France.

Measurement

Many reviews have been published on tenderness measurement. In one of them SZCZESNIAK and TORGESON (1965) wrote "as paradoxical as it may seem, studies on the causes of toughness are hampered by lack of fully reliable methods of measuring tenderness, while the development of such methods is seriously handicapped by the incomplete basic knowledge of the underlying principles of tenderness".

Fortunately, in the last ten years a lot of progress has been made in this field, but the ideal method to measure it is still not established.

Numerous methods have been developed to measure tenderness or toughness. The general and oldest method is consumption of a meat sample. Scientifically developed, it is presently known as "taste panel assessment". It is certainly the best method but the validity of the panel evaluation for a given country can be different according to the habits of consumption, and depends on the training of the judges, especially the repeatability and accuracy of their judgment. Special methods of selection and the use of panels will be discussed elsewhere (J.M. HARRIES 1975). In any case, the taste panel remains the reference method even if it is sometimes difficult to collect and retain all members through long experiments. But, owing to this difficulty, physical measurements are often preferred.

The operations of the various instruments used for evaluating meat tenderness are based on the study of metals in shearing, mincing, biting, puncturing... Among the numerous instruments developed to measure tenderness, the Warner Bratzler shear force apparatus is certainly the most popular and it is used in many laboratories all over the world. Since 1930 many others types have been tested : Instrom, Volokevich, Kramer... In our laboratory, one has been specially designed for measuring the effort of cutting and the work during this operation (SALE, 1971).

The first question is what to measure. Many research workers consider the shear force in force per unit area. The Newton per cm^2 must certainly be the most useful.

For some laboratories the compressing strenght or even the coefficients drawn from the curve of the process of compression are used as criteria of tenderness or measures of structure.

SEGARS et al (1974), for instance, use different coefficients, and calculate the apparent modulus of elasticity Ea.

These different physical measurements are certainly interesting to consider in special conditions but they are too complicated for cooperative work between foreign laboratories. The shear force seems suitable to evaluate tenderness at this level, and apparatus in use in most laboratories is designed to take this measurement quickly.

The shape of the core to be cut is important to consider. Tradtionally, with W.B. apparatus, the core is round. This form can be very easily taken from a cooked piece of meat. On raw meat, in some circumstances, even taken with a cork borer,it is difficult to ensure that the cut core is cylindrical and it is often biconical. The central part, where shearing is made, can be depressed and tenderness may appear too high.

The correction for thickness cannot be made by a simple calculation of the ratio strengh/thickness, because the mechanical properties of the meat are not homogeneous from one muscle to another or even inside the same muscle. The method of correction proposed by SALE and TOURAILLE (1973) is based on the measure of the shear force for different thickness and the calculations by regression of the right value for a standard thickness. The core of meat in this case has in general a prismatic shape with a rectangular section whose main dimension must be regular and near 1 cm. Finally the most suitable section which can give an idea of meat tenderness has an area of 1 cm^2. This area is the nearest to the average bite of meat taken and this value is also choosen by JOSEPH and CONNOLLY (1974).

A big difficulty remains with the shear force value calculated or directly measured : it is the large coefficient of variation generally obtained. With the W.B. apparatus, this coefficient is in general around 25 %. This value is largely in connection with the meat structure but even with a homogeneous product the coefficient of variation is always high (HURWICZ and TISCHER,1954).

The main objective of improvement of the apparatus used in shear force estimation is reduction of this variation.

Another aspect is the number of readings to obtain a representative value of the tenderness. This number is limited not only by the time necessary but by the variation in the piece of meat itself. Generally, it is not easy to take more than ten to twelve cutting values. Inside the muscle, the variation of tenderness (or other factors) is well known ; some workers for example SEGARS et al (1974), tried to trace a map of it. This work must be continued for all muscles considered to be economically significant. Already the structural aspect has been explored by NAUDE and JOSEPH (1970) ; they describe in accurate terms the orientation of fibres which are present in the samples of meat studied by everyone who measures tenderness.

The question : "how many muscles must be taken to obtain a value of the mean carcass tenderness ?" takes longer to discuss. Perhaps this discussion is already "out of fashion" because in the near future, meat will be sold not as whole carcasses , but as separate muscles.

In the meantime, if we have to measure the tenderness of a carcass, two muscles can be proposed : one relatively tender, the other relatively tough. In our laboratory we use the longissimus dorsi and the pectoralis profundus, because of the ease in removing them from the carcass without excessive loss of the commercial value of the carcass.

For RHODES (1975) one muscle,the longissimus dorsi is sufficient because its correlation with other muscles gives a reliable general value for tenderness.

DUMONT (1971) maintains that it is quite unrealistic to use one muscle only. The correlations between muscles in tenderness are in general positive but too small. "For that reason it is not possible to propose a general rather simple toughness index". In L. BUTCHER's work (1971) the correlation between longissimus dorsi tenderness and triceps brachii or semitendinosus tenderness is low (0.4) in each case.

DUMONT's values were obtained on fresh meat, and in BUCHTER's work the meat was cooked.

The measurement of tenderness of cooked meat is certainly most relevant to the consumer. But how variable are cooking methods throughout Europe and the whole world ? Measurement of toughness of raw meat seems more relevant to the practice of eating the more tender steaks (cooked rare) in France. But to improve the tenderness of pieces of meat rich in collagen, it is necessary to cook them in water around boiling temperature. The worst cooking conditions are certainly in the temperature range where the collagen shrinks but without any gelatinisation and where fibrillar and sarcoplasmic proteins are coagulated.

Measured on raw or cooked meat, the temperature of the core can introduce a variation in the results. For raw meat, the right temperature for cutting the sample is between 0 and 4°C and the same temperature seems suitable for measurement because of the ease of keeping it as this temperature with refrigeration and cold rooms. The handling of cooked meat is certainly more complicated and no systematic studies seem to be available which give the best temperature of measurement after cooking and the delay after cooking.

Elapsed time between slaughtering and the evaluation of tenderness is certainly the factor best known by the butchers. They know the different waiting period for maximum tenderness in the different types of production, young bull or cow for instance (VALIN et al., 1975).

Finally, in view of these difficulties, what is the best method of measuring tenderness ? Which factors of tenderness must we focus most attention on ? Technological factors (transport, stunning, storage...) are important but easy to control. Biological factors are also important but can only be controlled through selected breeding and management and therefore take a longer time to change. In particular it is important to consider the connective tissue content, its cross linking and distribution inside the muscle (BOCCARD et al 1967 - BOCCARD 1973).

Both shear force and collagen measurements reflect the effects of both types of factors and should be adopted by everyone.

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COLOUR ASPECTS IN BEEF

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Abstract

This review discusses colour aspects in beef covering the extensive handling between the live animal and the retail pack. Colour must never be regarded as an independent quality criterion of beef because other factors influence the overall colour appearance. Insufficient attention given to the procurement of optimal conditions during handling, packaging and storage of meat may outweigh all efforts made earlier, during the live animal or carcass stage, to ensure maximum carcass quality.

There remains an urgent need for a reliable objective method of colour measurement to be standardized for application in all EEC-countries.

Colour appreciation

The assertion that the colour of meat is generally considered to be an important aspect of quality in fresh beef is beyond doubt. When buying meat the consumer has to decide on its acceptability based on its appearance. In this connection the colour can never be regarded as an independent quality variable because colour perception is correlated with other variables, such as the slicing direction (cut), the structure of muscle groups, the wetness of the meat surface and the amount of intramuscular fat (marbling).

Although the perceivable colour of fresh meat has something to do with the amount of muscle pigment present, it should be borne in mind that the concentration of the muscle pigment myoglobin (plus any residual haemoglobin from the blood) as such can never be an accurate standard for the colour of fresh beef.

The visual perception of the colour of beef is in fact the sum of the partial reflectance contributions of the specific chemical forms of the meat pigment i.e. the dark purple colour of reduced myoglobin (Mb), the bright red colour of the oxygenated form oxymyoglobin (MbO_2) and the unwanted dull brown colour of the oxidation product metmyoglobin (MMb^+).

Generally, beef has an attractive red colour - associated by the consumer with freshness - when the main part of the meat pigment present in the surface layer of the beef cut is oxygenated. This biochemical 'situation' should coincide with the moment the consumer buys the meat regardless of previous handling, or the vicissitudes of the live animal.

Colour and the live animal

Although in the foregoing the total pigment content of beef was regarded as an inaccurate criterion for the evaluation of the colour appearance, the capacity for colour formation naturally depends on the amount of meat pigment present in the muscle tissue. Apart from other factors to be discussed later, the correlation between pigment content and colour formation can be considered in terms of the living animal.

It is well known that young calves have a relatively low pigment content with regard to mature animals, therefore producing paler meat cuts. This has eventually led to the consumer identifying veal with pale colouring and the selective breeding of anaemic types almost devoid of myoglobin.

The question arises what characteristics of the live animal influence the overall pigment concentration in the muscle. The relevant literature does not seem to be abundant and moreover experimental results can never be regarded as being free from effects on colour appearance.

Sex is an important factor affecting the colour of the meat and the muscle pigmentation.
In comparing quality aspects between entire male animals and castrated species the colour of bull meat usually turns out to be darker than steer meat (Wickens and Ball, 1967). The difference should be attributed to the bulls having a more physiological mature carcass with darker and coarser lean when compared with steers castrated at different ages. When interpreting the colour difference just mentioned various factors should be taken into account. The slaughter handling of bulls will for instance involve greater risk, resulting in more stress and leading to a higher value of the

ultimate pH and ultimate rejection of the meat due to dark cutting. Careful selection of abattoir conditions and extra caution in handling entire male animals, however, might prevent the occurrence of dark cutting beef and could lead to a normal pH value and an acceptable colour appearance. In comparing the overall quality of meat from male and non-male animals it was shown by Turnton (1969) that colour (and other quality) differences at an age of 12 months were small and not likely to have practical importance. If animals of the same breed, age and weight reared under identical conditions are compared with regard to the colour of the M. longissimus dorsi the colour of the bull joints can be even lighter than that of the steers, as can be seen in Table 1, published by Rhodes (1969).

Table 1. The colour of meat from the longissimus dorsi of intensively fed bulls and steers compared with that of barley fed and grass fed animals from normal market production. (Lightness value, Gardner Colour Meter).

		Lightness value *
Bulls	2 animals, intensive rearing	36.3
Steers	3 animals, intensive rearing	33.3
Steers	13 animals, barley fed (1 year)	30.5
Steers	20 animals, grass fed (2 years)	27.6

* zero = black; 100 = white.

The conclusion to be drawn is that sex cannot be dissociated from other characteristics such as age, maturity and last but not least pre-slaughter conditions. Contrasting results found with entire male animals purchased from the meat trade can be traced back to the fact that bull meat is derived from discarded breeding animals, being fully mature and of advanced age with biological effects of sex at their maximum.

For similar reasons difficulties can be expected when comparing colour 'qualities' of bulls and cows. Both sexes have different patterns in attaining maturity, thus comparing animals of the same weight and age is not without risk. In addition the feeding level during the fattening period strongly affects the animals weight-age correlation at the time of slaughter (Weniger and Steinhauf, 1969). Within each sex the differences in total pigment content are mainly due to age variations.

The breed to which the animal belongs is usually also considered to influence the colour of beef. The assumption is disputable since the factor of breed alone does not strongly affect the colour when other variables, such as age and/or live weight are more or less standarized. In a recent publication Hawrysh and Berg (1975) found minimal differences in colour ratings of both eye of round (M. semitendinosus) and loin (M. longissimus dorsi) cuts originating from bulls of five breeds or cross-breeds. These animals had an average live weight of 500 kg and differed in age at being slaughtered only between 400 and 450 days.

Colour appearance and stability of wholesale and retail cuts

Even when requirements to obtain an optimal carcass quality are complied with, the fact remains that the meat in question usually has to travel a long way to reach the consumer. The highly perishable product is more and more frequently bought in self-service stores where it is displayed in retail packs. Between the carcass and consumer size cuts lies the handling of meat at central packing stations, which have come into existence mainly for economic reasons. The extra long time involved in reaching the consumer requires an increased shelf-life and thus protection - by proper handling and packaging - from the ravages of bacteria, moisture loss, colour deterioration and odour formation.

In this connection, some biochemical aspects concerning colour formation and retention are worth mentioning. The appealing colour of fresh meat is mainly determined by the amount of oxymyoglobin (MbO_2) present in the approximately 2 mm thick top layer of the cut surface. The MbO_2 is formed by a reversible combination of reduced myoglobin (Mb) with molecular oxygen from the atmosphere. This oxygenation process is called blooming. When the bright red surface is freely exposed to the air for several days, an additional reaction can occur, which is an essentially non-reversible oxidation whereby the highly stable metmyoglobin (MMb^+) is formed. The latter undesirable reaction is dependent on the partial oxygen pressure, being at maximum speed at low oxygen pressures of approximately 1 - 4 mm Hg (Govindarajan, 1973).

Since most of the biological processes associated with living muscle tissue are usually still operative in fresh beef, there is an indirect possibility of converting MMb^+ back into Mb. Reducing coenzymes are operative in this process. The residual reducing activity in meat may also cause a rapid drop in partial oxygen pressure if the cut is packed in a film with very low oxygen permeability. In that case optimal conditions for the oxidation to MMb^+ are created. Thus, a freshly cut piece of meat should be wrapped in an oxygen permeable film to ensure a maximal shelf-life. The latter, however, remains restricted to 3 - 4 days because even under 'oxygen-rich' conditions a sufficient amount of MMb^+ is formed to cause colour deterioration. The formation of MMb^+ is also dependent on temperature, pH-value and bacterial concentration.

Since oxygen utilization by meat first occurs through a diffusion process with a preceding dissolution of the gas in the surface fluid, a low storage temperature should be obtained since the solubility of O_2 will then be increased. The low temperature also inhibits growth of micro-organisms and consequently of competitors for the available oxygen. However, there is actually no real difference between the bacteriological characteristics of wrapped and unwrapped meat and both are equally perishable and sensitive to microbial attack. For this reason, the initial bacterial count should be minimized by proper sanitation and automation of processing-packaging production programmes.

For several reasons the pH of the meat is important. Firstly bacterial spoilage is accelerated in the higher pH range. Secondly increased pH-values have a significant, positive effect on the water binding capacity of meat proteins - to be further discussed during this seminar by Professor Hamm from Kulmbach - resulting in a subsequent decrease in the muscle fluid phase and a more tightly packed, compact structure. In fact this is the reason for the defective appearance of dark cutting beef.

Another reason for colour deterioration is surface dehydration. When the relative humidity (RH) of the surrounding atmosphere is too low i.e. below 85% RH, evaporation of moisture occurs resulting in pigment concentration and its increased oxidation. Therefore the temperature in modern coolers used for the storage of fresh meat should not exceed 1.5 - 3°C while the prevalent RH-values should be in the range of 80 - 85% RH. The packaging material should have a high oxygen but a low water permeability. Giving insufficient attention to secure these conditions may be detrimental to all efforts made earlier to ensure optimal quality of the carcass or even the live animal.

Subjective and objective colour measurement

Meat colour is in fact a surface property. It can be measured by subjective evaluation or objectively by means of instruments. In both cases, as mentioned before, the sum of the partial reflectance contributions of Mb, MbO_2 and MMb^+ is determined. Subjective colour evaluation is far from being an easy operation. Generally it is performed by matching against a standard which introduces the problem of selecting the proper one. Moreover there is a difference in colour scales used in the evaluation. For example in the literature the use of a 10-point scale is mentioned (van den Oord et al., 1971); 1 = extremely bad and 10 is extremely good. Mac Dougall et al. (1972) described a 9-point scale in which 1 represents an extremely pale sample and 9 corresponds to an extremely dark piece of meat, the ideal colour of an optimally bloomed sample lying in between.

Another variable in the subjective visual colour appearance is the kind of fluorescent light used in rooms and cabinets where meat is displayed. A systematic search at our Institute for the best lamp to be used, showed that this aspect should by no means be underestimated.

It is obvious that difficulties in subjective colour evaluation have led to a substantial search for objective colour measurement. A logical development in this connection appeared to be the extraction of the oxidized and reduced forms of the pigment and the spectrophotometric determination of the relevant concentrations (Dean and Ball, 1960). This procedure introduces artefacts of two kinds. Firstly, meat colour is a surface property, while the pigment concentration obtained by extraction might also represent the pigment from the interior of the meat. Secondly, extraction procedures in the presence of oxygen will lead to quantities of myoglobin derivatives not originally present in the meat. For this reason the 'non-destructive' determination of the reflectance spectra of meat samples should be preferred.

It is not opportune to go into all details of the theoretical aspects connected with reflectance spectrophotometry. In short the principle is that light falling on an opaque meat surface is partly absorbed, and partly scattered. The proportion of the light absorbed by the meat pigments to that absorbed by the matrix of the solids decreases with increasing reflectivity. The reflectivity, R_∞, depends on the ratio of the absorption coefficient K and the scattering coefficient S in the following way: $K/S = (1-R_\infty)^2/2R_\infty$.

The importance of this equation manifests itself in the linear relationship between the K/S ratio and the concentration of pigment at a given wavelength.

In this way the proportion of MbO_2 and MMb^+ can be determined in meat surfaces (van den Oord et al., 1971). The objective results have a highly significant correlation ($r = 0.94$) with those of the subjective colour evaluation of a trained panel. Beef was unacceptable to this panel when the MbO_2 level dropped to 50%.

When bright red beef and discoloured beef are displayed together in a supermarket, shopper discrimination against the discoloured meat increases with the rise in metmyoglobin content, as was determined by spectrophotometry (Hood et al., 1973).

Another way to objectively measure colour is the use of an automatic colour difference meter scaled in Hunter units of L(lightness), a_L(redness) and b_L(yellowness), from which the hue ($H = \tan^{-1} b_L/a_L$) and the saturation $S = (a_L^2+b_L^2)^{\frac{1}{2}}$ can be calculated. The instrument is standarized on a red 'meat' tile. In measuring these L, a, b units, Snyder (1964, 1965) found that a/b values correlate with the oxidation 'progress' of the meat pigment.

The fact remains that no single variable can be found or calculated which correlates directly with colour appearance. This view can be extended to instruments like the Göfö or Fahellpho, which - apart from being objective in a way - appeared to be by no means more accurate than the trained eye.

The foregoing considerations lead to the conclusion that there remains an urgent need for a reliable method of colour measurement.

General conclusion

From the above review, which is far from exhaustive, some general inferences can be drawn. The criterion of quality in beef must never be based on a single independent measurement. When colour is included in the efforts to obtain an optimal quality of carcasses or even live animals, it should be borne in mind that in the end the colour of meat cuts derived from them, strongly influences the consumers choice. Therefore the dead-line is the moment at which the meat is displayed in retail pack in refrigerated cabinets. A new trend in meat packaging, the centralized prepackaging, requires increased shelf-life to be attained by proper sanitation and handling.

There remains an urgent need for a reliable objective method of colour measurement, both for carcass grading and evaluation of colour of 'in-store' meat samples. The method should not be too time consuming and will have to be standarized for application in all EEC-countries.

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COLOUR EVALUATION OF MUSCLES IN 10 BOVINE CROSSBREEDS*

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Abstract

The analysis of 6 different muscles obtained from 40 carcasses of 10 crossbred beef cattle (Tables 1 and 2) has shown the importance of breed (mainly the paternal one), of muscle and of the interaction between paternal and maternal breeds on meat colour evaluation (Table 3).

Crosses from the same paternal breed reached different levels in relation to the dominant wavelength considered: Piedmont crosses have always shown the lowest reflectance; on the contrary, Romagna crosses have shown the highest one. The brightness, measured as the human eye response to percentage reflectance, seems to have a practical usefulness: the Chiana crossbred meat had an area of neutral colour larger than that of the Piedmont; in other words, meat from Chiana crossbreds was brighter than that from Piedmont (Table 7). The dominant wavelength was not statistically significant, while for the Piedmont crossbreds the purity of dominant wavelength was significantly higher than for the others.

The maternal breed is not statistically significant (Table 3) even if the BA crosses seem to have meat which is slightly brighter than the IF crosses.

The interaction between paternal and maternal breeds was due mainly to CxIF and RPFxIF crossbreeds.

Muscle is invariant in relation to crossbreeds and it occupies almost always the same rank in the spectrophotometric curve, showing its individuality and confirming its histochemical characteristics. Among the various muscles studied the Ss was the darkest and the Sm and St the brightest (Table 4).

Introduction

Consumer acceptance is dependent to a large extent upon colour of meat. It seems therefore important to know the factors affecting these characteristics in order

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to improve the commercial value of meat. This knowledge in practical use should be considered within a system of several variables each one weighted individually to improve the system. The present paper is part of a large programme of research within the area of beef cattle evaluation 'in vivo' and after slaughtering (Matassino et al., 1974, 1975a, b, c; Cosentino et al., 1975).

Several factors and their interrelationships are involved in the colour evaluation: the species, the age, myoglobin and haemoglobin concentration (Lawrie, 1974; Romans et al., 1965; Charpentier, 1966; Price and Schweigert, 1971), pH variation during aging (Callow, 1938; Bate-Smith, 1948; Lawrie, 1974; Martin et al., 1971; Price and Schweigert, 1971), marbling level (Romans et al., 1965), storage temperature (Snyder, 1964), bacterial activity (Kraft and Ayres, 1952; Butler et al., 1953), exposure to light in display cases (Watts, 1954; Kraft and Ayres, 1954), dehydration degree (Urbin and Wilson, 1958), haematocrit (Charpentier, 1966), motor activity and 'rigor mortis'. To obtain objective and comparable data it is necessary to make colour measurements using a reflectance spectrophotometer and to employ selective filters.

In this paper we have investigated the significance of the breed and of the muscles in the evaluation of colour.

Materials and Methods

The experiment was conducted on 40 carcasses of the following 10 crossbred beef cattle:

1. Chiana x Brown Alpine (CxBA)
2. Chiana x Italian Friesian (CxIF)
3. Red Pied Friuli x Brown Alpine (RPFxBA)
4. Red Pied Friuli x Italian Friesian (RPFxIF)
5. Marche x Brown Alpine (MxBA)
6. Marche x Italian Friesian (MxIF)
7. Piedmont x Brown Alpine (PxBA)
8. Piedmont x Italian Friesian (PxIF)
9. Romagna x Brown Alpine (RxBA)
10. Romagna x Italian Friesian (RxIF).

The techniques of breeding, slaughtering and cutting were suitably standardized. Average values of some variables referring to 4 animals, within each of the above categories, are reported in Table 1. The muscles in the study are listed in Table 2. The observations were carried out after 5 days of carcass aging at 0-2^{o}C, using the reflectance spectrophotometers EEL (England) and Göfö (Schütt, Germany). The first one gives a curve (see, for example, Fig. 1), the

Table 1. Values of some variables at slaughter.

Crossbreed	Weight, kg					
	live		live net (1)		utilized side	
	$\bar{x} \pm \sigma$	CV %	$\bar{x} \pm \sigma$	CV %	$\bar{x} \pm \sigma$	CV %
CxBA	496.4 ± 5.5	1	461.5 ± 4.3	1	146.9 ± 5.6	4
CxIF	498.8 ±14.2	3	462.2 ±14.5	3	145.1 ± 5.3	4
RPFxBA	505.9 ± 7.8	2	464.2 ± 8.3	2	143.4 ± 3.4	2
RPFxIF	502.6 ±10.6	2	462.8 ± 8.1	2	144.2 ± 2.4	2
MxBA	491.9 ± 8.5	2	453.0 ± 8.1	2	143.7 ± 3.7	3
MxIF	497.5 ± 6.8	1	460.3 ± 7.3	2	144.7 ± 5.8	4
PxBA	494.8 ± 5.2	1	461.6 ± 5.9	1	149.4 ± 3.2	2
PxIF	498.6 ± 9.2	2	460.9 ± 8.3	2	149.9 ± 1.8	1
RxBA	492.8 ± 3.6	1	454.0 ± 2.8	1	143.0 ± 1.3	1
RxIF	496.0 ± 9.1	2	455.4 ± 9.1	2	142.3 ± 4.4	3

(1) Live weight at slaughter with the weights of the gut content substracted.

Table 2. - Tested muscles.

Muscle	Symbol	Cut (1)
Supraspinatus	Ss	Chuck
Rhomboideus cervicis	RC	Chuck rib
Semitendinosus	St	Silverside
Gluteobiceps	Gb	Topside
Semimembranosus	Sm	Round
Longissimus dorsi (2)	LD	Sirloin

(1) Strother (1974). (2) Three samples, a, b, c.

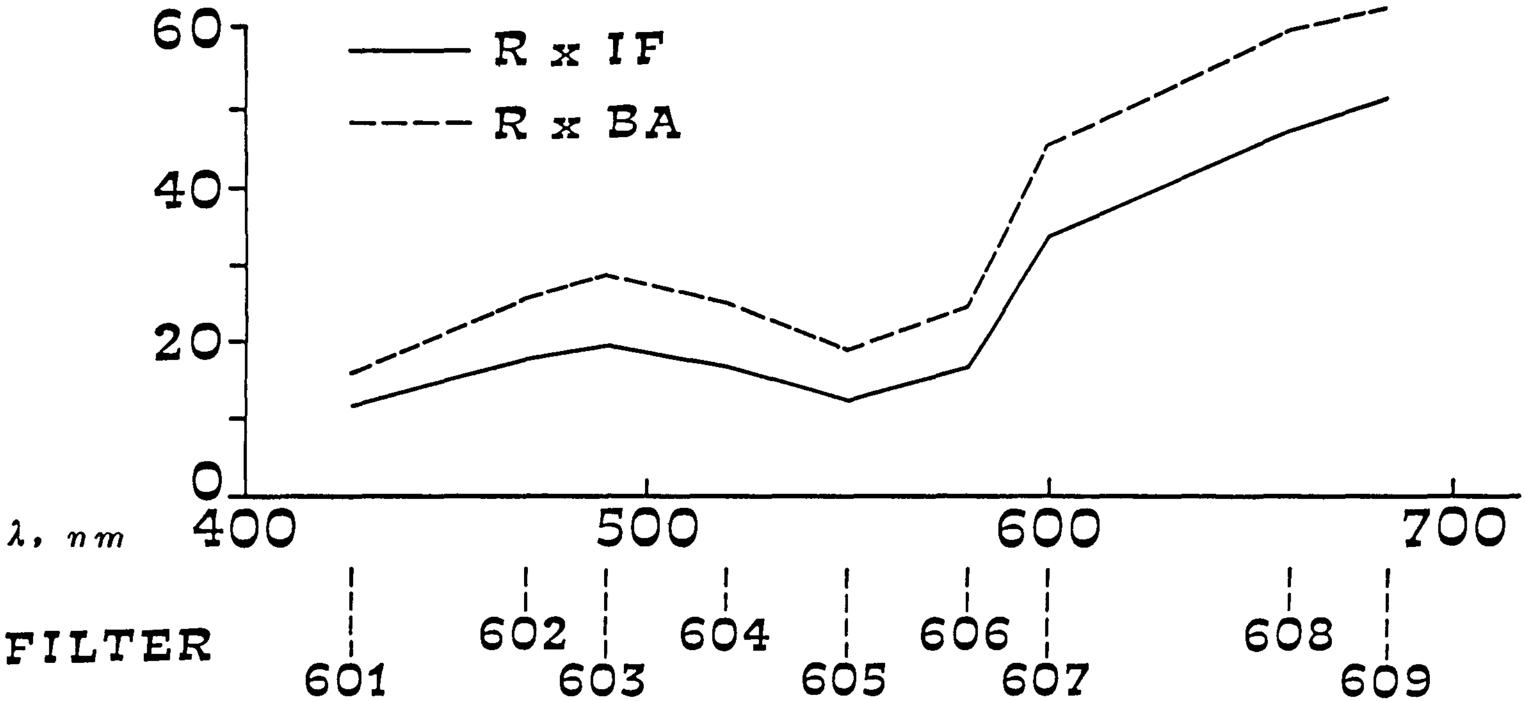

Fig. 1. Spectrophotometric curve.

brightness, the dominant wavelength (λ) and purity. The last two variables were calculated as suggested by the Commission Internationale d'Eclairage (CIE).

Results and Discussion

The muscle (Mu) is one of the most important factors affecting the variation of the studied variables with the exception of the dominant wavelength and the purity; it is followed by the paternal breed effect (P), whereas the maternal (M) is not significant; the interaction P-M is almost always statistically significant; on the contrary, the interactions P-Mu, M-Mu and P-M-Mu are not statistically significant (Table 3). The remarkable individuality of muscle is

Table 3. Results of some statistical analyses.

Variable	F (1)			
	between			interaction (2)
	breed		muscle, Mu	P-M
	paternal, P	maternal, M		
Filter: 601	6.2***	7.6**	15.6***	3.8**
602	5.5***	4.0*	19.7***	3.4***
603	6.0***	2.3	19.8***	3.6**
604	5.7***	2.9	22.0***	4.7***
605	5.8***	6.2*	21.8***	4.3**
606	4.8***	2.7	22.6***	4.3**
607	3.3*	1.9	20.2***	1.8
608	3.7**	2.8	19.6***	2.6*
609	8.8***	0.1	21.2***	2.9*
Brightness, %	5.7***	0.3	21.2***	4.3**
λ dominant, mμ	1.7	0.1	0.8	1.4
Purity, %	3.9**	2.7	1.8	2.4*
Brightness, μA (3)	14.7***	0.1	23.2***	0.8

(1) * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

(2) P-Mu, M-Mu and P-M-Mu not significant.

(3) Göfö, E. Schütt, Göttingen, Germany.

Table 4. Value (V) of same colour variables of different muscles (Mu) making them relative to those of muscle St (= 100).

Variable													
601		602		603		604		605		606		607	
Mu	V	Mu	V	Mu	V	Mu	V	Mu	V	Mu	V	Mu	V
Sm	103.6	Sm	100.6	St	100.0	Sm	101.3	Sm	103.6	Sm	101.6	Sm	100.5
St	100.0	St	100.0	Sm	99.6	St	100.0	St	100.0	St	100.0	St	100.0
Gb	92.2	Gb	90.0	Gb	87.5	Gb	87.8	Gb	86.8	Gb	88.2	Gb	92.0
RC	88.6	RC	84.3	RC	83.4	LD_a	83.4	LD_a	83.0	LD_a	83.0	RC	85.9
LD_a	88.1	LD_a	84.1	LD_a	83.2	RC	81.4	RC	81.8	RC	82.3	LD_a	83.8
LD_c	88.1	LD_c	82.5	LD_c	81.1	LD_c	80.1	LD_b	80.4	LD_b	79.6	LD_c	83.1
LD_b	86.8	LD_b	82.1	LD_b	80.4	LD_b	78.8	LD_c	80.3	LD_c	79.4	LD_b	81.4
Ss	77.7	Ss	75.9	Ss	74.5	Ss	74.0	Ss	74.6	Ss	74.7	Ss	77.7

Variable											
608		609		brightness,%		λ dominant,nm		purity,%		brightness,μA	
Mu	V	Mu	V	Mu	V	Mu	V	Mu	V	Mu	V
Sm	102.4	Sm	104.1	St	100.0	Ss	100.4	Gb	106.7	Ss	113.3
St	100.0	St	100.0	Sm	95.6	LD_c	100.3	Ss	104.9	LD_c	112.5
Gb	95.5	Gb	95.6	Gb	88.8	Gb	100.3	St	100.0	LD_b	112.5
RC	90.0	RC	92.8	RC	85.9	LD_b	100.3	LD_b	99.0	LD_a	112.0
LD_a	86.8	LD_a	87.3	LD_a	82.4	LD_a	100.3	Sm	97.5	RC	108.4
LD_c	85.4	LD_c	86.3	LD_c	80.3	Sm	100.3	RC	97.5	Gb	106.3
LD_b	84.2	Ss	85.5	LD_b	78.2	RC	100.2	LD_c	97.3	Sm	103.6
Ss	83.3	LD_b	85.3	Ss	72.2	St	100.0	LD_a	93.6	St	100.0

clearly shown in Table 4: within the filter, the Ss muscle always ranking last, the Sm first and the St second. The absence of significant interaction between muscle and crossbreed would indicate that the rank of colorimetric values, among muscles, is invariant in relation to the crossbreed. This result, as already observed with other characteristics (Matassino et al., 1974, 1975a, b; Bordi et al., 1975; Cosentino et al., 1975), can be useful for genetic improvement.

The Ss muscle without each filter shows a lower percentage of reflectance than other muscles and consequently a larger area of neutral colour (achromatic); this means that the Ss has more chromogenes, and therefore it absorbs in relation to the other muscles more beams of monochromatic light in the following three ranges, indicated in a decreasing order of absorption: 520-580 nm (green), 426-490 nm (blue), 600-684 nm (red). The opposite was observed using the Sm muscle. The rank scale arranged for brightness and measured as the 'average eye' response to percentage reflectance, points out that the Ss is the darkest muscle and the St is the brightest (the difference between the two being equal to 30 per cent). The brightness measured with Göfö (μA) confirms this rank (Table 4). The dominant λ, measured between the two complementary values -492 and -511, does not vary statistically among the muscles; the purity of dominant λ behaves in the same manner, its values lying between 25.53 and 43.83 per cent. The individuality of muscles is also pointed out by the incidence of the muscle component on the total variance; the value of this component is about 1/3 either within filter or within brightness (Table 5). About 70 per cent of the comparisons between muscles are almost always significant (Table 6). The histochemical muscle individuality had been shown as early as 1874 by Ranvier who reported that muscles, in relation to their main function which is the transformation of chemical into mechanical energy, behave differently: the 'white' muscles contract suddenly and can therefore be considered 'active' muscle, while the 'red' muscles contract slowly and persistently and are considered 'balancing' or 'regulating' muscles. Myofibrillar proteins are qualitatively different (Parsons et al., 1969; Sarkar et al., 1971). The 'red' muscles have a higher activity of protein synthesis (Dreyfus, 1967; Goldberg, 1967; Short, 1969). The best known difference between 'white' and 'red' muscles is the different way they supply energy: the 'red' fibres depend especially on oxidative metabolism, and they can be active for a long time; the 'white' fibres, on the other hand, through their high rate of glycolysis, are suited to sudden and voluntary contractions (Burleigh and Schimke, 1968, 1969; Bass et al., 1969). Ansay (1974) reported that the animals from Moyenne and Haute Belgique bovine breeds have remarkably faint hexokinase activity in the 'psoas major' muscle, which is about ten times

Table 5. Variance components and their percentage of the total.

Variable	Component				
	breed		muscle, Mu	interaction (1)	error
	paternal, P	maternal, M		P-M	
Filter: 601	5.1	2.6	23.1	5.5	63.6
602	4.3	1.1	28.6	4.7	61.3
603	4.8	0	28.8	5.1	61.3
604	4.3	0	30.7	6.7	58.4
605	4.3	1.9	30.0	6.0	57.8
606	3.5	0	31.6	6.2	58.7
607	2.4	0	31.7	0	65.9
608	2.7	0	29.8	3.2	64.2
609	7.3	0	29.9	3.6	59.3
Brightness, %	4.4	0	30.0	6.2	59.4
λ dominant, nm	0	0	0	0	0
Purity, %	4.2	0	0	3.9	91.9
Brightness, μA	12.1	0	31.3	0	56.6

(1) P-Mu, M-Mu and P-M-Mu not significant.

smaller than St, and intermediate in LD and 'biceps femoris' muscles.

Within paternal breed, the Piedmont crossbreeds show a meat reflectance and brightness always lower than other crossbreeds. The paternal breed is not statistically significant for the dominant λ and the opposite is observed for the purity where the difference between the two extreme values is about 1/10 (Table 7). The crossbreed PxIF shows a meat reflectance value always lower than other crossbreeds (Table 8). The significant differences among crossbreeds are shown in Table 9. The range reaches the maximum (> 20 per cent) for the dominant wavelengths 520-580 nm, followed by the 426-490 nm (< 20 per cent) and by the 600-684 nm (∿ 12 per cent). RxBA and CxIF crossbreeds give meat which is remarkably bright and correspondingly pale. The dominant λ gave the same results, while its purity presented the highst value in the PxBA crossbreeds (Table 8).

In relation to maternal breed, the BA hybrids seem to supply meat slightly brighter than those from IF. The interaction between paternal and maternal breed (P-M) is due especially to crossbreeds CxIF and RPFxIF, meaning that the IF hybrids have a meat reflectance higher than the BA hybrids, only at the wave-

Table 6. Significant comparisons between muscles, obtained with q test.

Muscles

1. Filter 601

- Sm -Ss**
- Sm -LD_b**
- Sm -LD_c**
- Sm -LD_a**
- Sm -RC**
- Sm -Gb**
- St -Ss**
- St -LD_b**
- St -LD_c**
- St -LD_a**
- St -RC**
- St -Gb**
- Gb -Ss**
- RC -Ss**
- LD_a -Ss**
- LD_c -Ss**
- LD_b -Ss**

2. Filter 602

- Sm -Ss**
- Sm -LD_b**
- Sm -LD_c**
- Sm -LD_a**
- Sm -RC**
- Sm -Gb**
- St -Ss**
- St -LD_b**
- St -LD_c**
- St -LD_a**
- St -RC**
- St -Gb**
- Gb -Ss**
- Gb -LD_b*
- Gb -LD_c*
- RC -Ss*
- LD_a -Ss*
- LD_b -Ss*

3. Filter 603

- St -Ss**
- St -LD_b**
- St -LD_c**
- St -LD_a**
- St -RC**
- St -Gb**
- Sm -Ss**
- Sm -LD_b**
- Sm -LD_c**
- Sm -LD_a**
- Sm -RC**
- Sm -Gb**
- Gb -Ss**
- RC -Ss*
- LD_a -Ss*
- LD_b -Ss*

4. Filter 604

- Sm -Ss**
- Sm -LD_b**
- Sm -LD_c**
- Sm -RC**
- Sm -LD_a**
- Sm -Gb**
- St -Ss**
- St -LD_b**
- St -LD_c**
- St -RC**
- St -LD_a**
- St -Gb**
- Gb -Ss**
- Gb -LD_b*
- LD_a -Ss*

5. Filter 605

- Sm -Ss**
- Sm -LD_c**
- Sm -LD_b**
- Sm -RC**
- Sm -LD_a**
- Sm -Gb**
- St -Ss**
- St -LD_c**
- St -LD_b**
- St -RC**
- St -LD_a**
- St -Gb**
- Gb -Ss**

6. Filter 606

- Sm -Ss**
- Sm -LD_c**
- Sm -LD_b**
- Sm -RC**
- Sm -LD_a**
- Sm -Gb**
- St -Ss**
- St -LD_c**
- St -LD_b**
- St -RC**
- St -LD_a**
- St -Gb**
- Gb -Ss**
- Gb -LD_c*
- Gb -LD_b*
- LD_a -Ss*

7. Filter 607

- Sm -Ss**
- Sm -LD_b**
- Sm -LD_c**
- Sm -LD_a**
- Sm -RC**
- Sm -Gb**
- St -Ss**
- St -LD_b**
- St -LD_c**
- St -LD_a**
- St -RC**
- St -Gb**
- Gb -Ss**
- Gb -LD_b**
- Gb -LD_c**
- Gb -LD_a**
- Gb -RC*
- RC -Ss*

8. Filter 608

- Sm -Ss**
- Sm -LD_b**
- Sm -LD_c**
- Sm -LD_a**
- Sm -RC**
- Sm -Gb*
- St -Ss**
- St -LD_b**
- St -LD_c**
- St -LD_a**
- St -RC**
- Gb -Ss**
- Gb -LD_b**
- Gb -LD_c**
- Gb -LD_a**
- Gb -RC*
- RC -Ss*

9. Filter 609

- Sm -LD_b**
- Sm -Ss**
- Sm -LD_c**
- Sm -LD_a**
- Sm -RC**
- Sm -Gb**
- St -LD_b**
- St -Ss**
- St -LD_c**
- St -LD_a**
- St -RC**
- St -Gb*
- Gb -LD_b**
- Gb -Ss**
- Gb -LD_c**
- Gb -LD_a**
- RC -LD_b**
- RC -Ss**
- RC -LD_c**

10. Brightness, %

- St -Ss**
- St -LD_b**
- St -LD_c**
- St -LD_a**
- St -RC**
- St -Gb**
- Sm -Ss**
- Sm -LD_b**
- Sm -LD_c**
- Sm -LD_a**
- Sm -RC**
- Sm -Gb*
- Gb -Ss**
- Gb -LD_b**
- Gb -LD_c*
- RC -Ss**
- RC -LD_b*
- LD_a -Ss**
- LD_c -Ss*
- LD_b -Ss*

11. Brightness, μA

- Ss -St**
- Ss -Sm**
- Ss -Gb**
- Ss -RC**
- LD_c -St**
- LD_c -Sm**
- LD_c -Gb**
- LD_b -St**
- LD_b -Sm**
- LD_b -Gb**
- LD_a -St**
- LD_a -Sm**
- LD_a -Gb**
- RC -St**
- RC -Sm**
- Gb -St**
- LD_c -RC*
- LD_b -RC*
- LD_a -RC*
- Sm -St*

Table 7. Values (V) of some colour variables of different breeds (B) making them relative to those of the paternal breed RPF (= 100).

Variable													
601		602		603		604		605		606		607	
B	V	B	V	B	V	B	V	B	V	B	V	B	V
R	102.8	R	105.1	R	104.2	R	102.7	R	102.6	R	100.6	RPF	100.0
C	101.7	C	103.2	C	103.2	C	100.9	RPF	100.0	RPF	100.0	C	99.3
M	101.1	M	100.2	RPF	100.0	RPF	100.0	C	99.2	C	99.4	R	97.7
RPF	100.0	RPF	100.0	M	99.3	M	98.1	M	97.8	M	97.8	M	96.3
P	91.8	P	94.0	P	92.4	P	90.9	P	90.2	P	90.6	P	92.4

Variable											
608		609		brightness,%		λ dominant, nm		purity,%		brightness, μA	
B	V	B	V	B	V	B	V	B	V	B	V
C	100.7	R	100.5	C	104.5	P	100.3	P	100.4	P	103.4
M	100.7	C	100.2	R	103.0	M	100.1	RPF	100.0	RPF	100.0
RPF	100.0	M	100.2	RPF	100.0	R	100.1	M	95.8	M	97.7
R	100.0	RPF	100.0	M	99.0	RPF	100.0	C	93.9	C	97.5
P	94.2	P	91.4	P	93.0	C	100.0	R	91.5	R	97.1

Table 8. Values (V) of same colour variables of different crossbreeds (C) making them relative to those of the crossbreed RPFxBA.

Variable													
601		602		603		604		605		606		607	
C	V	C	V	C	V	C	V	C	V	C	V	C	V
RxBA	109.8	RxBA	111.8	RxBA	112.5	RxBA	111.5	RxBA	111.4	RxBA	108.0	RxBA	101.7
MxBA	105.9	CxIF	105.2	CxIF	107.2	CxIF	105.9	CxIF	102.1	CxIF	104.1	CxIF	101.6
CxIF	103.2	MxBA	102.2	MxBA	103.1	RPFxIF	102.7	MxBA	101.4	RPFxIF	101.8	RPFxIF	100.5
CxBA	100.4	CxBA	100.9	RPFxIF	102.9	MxBA	102.1	RPFxIF	100.8	MxBA	101.0	RPFxBA	100.0
RPFxIF	100.3	RPFxBA	100.0	CxBA	102.1	RPFxBA	100.0	RPFxBA	100.0	RPFxBA	100.0	MxBA	98.4
RPFxBA	100.0	RPFxIF	99.7	RPFxBA	100.0	CxBA	98.7	CxBA	97.1	MxIF	96.5	CxBA	97.5
MxIF	96.5	RxIF	98.1	RxIF	98.9	MxIF	96.7	MxIF	95.0	CxBA	96.4	MxIF	94.7
RxIF	96.0	MxIF	97.7	MxIF	98.5	RxIF	96.7	RxIF	94.8	RxIF	95.1	PxBA	94.5
PxBA	92.8	PxBA	94.8	PxBA	95.1	PxBA	94.4	PxBA	92.9	PxBA	94.5	RxIF	94.2
PxIF	91.0	PxIF	92.9	PxIF	92.4	PxIF	89.8	PxIF	88.2	PxIF	88.6	PxIF	90.8

Variable											
608		609		brightness,%		λ dominant,nm		purity,%		brightness,μA	
C	V	C	V	C	V	C	V	C	V	C	V
MxBA	104.6	RxBA	104.2	RxBA	113.3	PxBA	100.2	PxBA	109.4	PxBA	104.3
RxBA	104.3	MxBA	103.4	CxIF	110.2	PxIF	100.1	RPFxIF	102.3	PxIF	102.9
CxIF	103.4	CxIF	102.4	RPFxIF	107.1	RxIF	100.1	PxIF	100.4	RPFxBA	100.0
RPFxIF	101.6	RPFxIF	101.9	CxBA	106.2	RPFxBA	100.0	MxIF	100.1	RPFxIF	99.4
RPFxBA	100.0	RPFxBA	100.0	MxBA	104.6	MxIF	99.9	RPFxBA	100.0	MxIF	98.0
CxBA	99.7	CxBA	99.9	MxIF	100.6	MxBA	99.9	CxIF	99.2	CxBA	97.8
MxIF	98.4	RxIF	98.8	RxIF	100.2	CxIF	99.9	RxIF	97.7	RxIF	97.7
RxIF	97.2	MxIF	98.8	RPFxBA	100.0	RxBA	99.8	MxBA	93.6	MxBA	97.1
PxBA	96.4	PxIF	94.7	PxIF	97.0	CxBA	99.7	CxBA	90.8	CxIF	97.0
PxIF	93.5	PxBA	89.9	PxBA	95.8	RPFxIF	99.7	RxBA	87.3	RxBA	95.9

Table 9. Significant comparisons between crossbreeds, obtained with q test.

Crossbreeds

1. Filter 601

(RxBA) - (PxIF)**
(RxBA) - (PxBA)**
(RxBA) - (RxIF)**
(RxBA) - (MxIF)**
(MxBA) - (PxIF)**
(MxBA) - (PxBA)**
(CxIF) - (PxIF)*

2. Filter 602

(RxBA) - (P xIF)**
(RxBA) - (P xBA)**
(RxBA) - (M xIF)**
(RxBA) - (R xIF)**
(RxBA) - (RPFxIF)*
(RxBA) - (RPFxBA)**
(RxBA) - (C xBA)*
(RxBA) - (M xBA)*
(CxIF) - (P xIF)*

3. Filter 603

(RxBA) - (P xIF)**
(RxBA) - (P xBA)**
(RxBA) - (M xIF)**
(RxBA) - (R xIF)**
(RxBA) - (RPFxBA)*
(CxIF) - (P xIF)**
(CxIF) - (P xBA)*

4. Filter 604

(R xBA) - (P xIF)**
(R xBA) - (P xBA)**
(R xBA) - (M xIF)**
(R xBA) - (R xIF)**
(R xBA) - (C xBA)*
(R xBA) - (RPFxBA)*
(C xIF) - (P xIF)**
(RPFxIF) - (P xIF)*
(M xBA) - (P xIF)*

5. Filter 605

(R xBA) - (P xIF)**
(R xBA) - (P xBA)**
(R xBA) - (R xIF)**
(R xBA) - (M xIF)**
(R xBA) - (C xBA)**
(R xBA) - (RPFxBA)*
(R xBA) - (RPFxIF)*
(R xBA) - (M xBA)*
(R xBA) - (C xIF)*
(C xIF) - (P xIF)*
(M xBA) - (P xIF)*
(RPFxIF) - (P xIF)*
(RPFxBA) - (P xIF)*

6. Filter 606

(R xBA) - (PxIF)**
(R xBA) - (PxBA)**
(R xBA) - (RxIF)*
(R xBA) - (CxBA)*
(R xBA) - (MxIF)*
(C xIF) - (PxIF)**
(RPFxIF) - (PxIF)**
(M xBA) - (PxIF)*
(RPFxBA) - (PxIF)*

7. Filter 607

(RxBA) - (PxIF)*
(CxIF) - (PxIF)*

8. Filter 608

(MxBA) - (PxIF)**
(RxBA) - (PxIF)**
(CxIF) - (PxIF)*

9. Filter 609

(R xBA) - (PxBA)**
(R xBA) - (PxIF)*
(M xBA) - (PxBA)**
(M xBA) - (PxIF)*
(C xIF) - (PxBA)**
(RPFxIF) - (PxBA)**
(RPFxBA) - (PxBA)**
(C xBA) - (PxBA)**
(M xIF) - (PxBA)**
(R xIF) - (PxBA)**

10. Brightness, %

(RxBA) - (P xBA)**
(RxBA) - (P xIF)**
(RxBA) - (RPFxBA)*
(RxBA) - (R xIF)*
(RxBA) - (M xIF)*
(CxIF) - (P xBA)**
(CxIF) - (P xIF)*

11. Purity, %

(PxBA) - (RxBA)**
(PxBA) - (CxBA)**
(PxBA) - (MxBA)*

12. Brightness, μA

(PxBA) - (R xBA)**
(PxBA) - (C xIF)**
(PxBA) - (M xBA)**
(PxBA) - (R xIF)**
(PxBA) - (C xBA)**
(PxBA) - (M xIF)**
(PxBA) - (RPFxIF)**
(PxBA) - (RPFxBA)**
(RxIF) - (R xBA)**
(PxIF) - (C xIF)**
(PxIF) - (M xBA)**
(PxIF) - (R xIF)**
(PxIF) - (C xBA)**
(PxIF) - (M xIF)**
(PxIF) - (RPFxIF)*
(PxIF) - (RPFxBA)*

lengths within the range of 520-580 nm. Also for some texture variables (hardness, chewiness and moisture release) the interaction P-M seems to be due to CxIF crossbreed (Matassino et al., 1975a).

This study has pointed out that breed and muscles are the two most important factors affecting meat colour and the technical procedures employed are of practical usefulness. Therefore, in evaluating carcass cuts, colour and texture characteristics should be added to the others more often used and, in addition, they should be included in any meat breeding programme.

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WATER-HOLDING CAPACITY

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Abstract

The differences in water-holding capacity (WHC) between different meat samples as well as the remarkable changes in WHC during storage and processing of meat are determined by the extent to which the non-tightly bound water (non-hydration water) is immobilised within the microstructure of tissue. There is a continuous transition from the water strongly immobilised, which can be expressed with difficulty, to the "loose" water which can be squeezed out by very low pressure. It is not possible, therefore, to get any absolute figures for the immobilised part of water because the amount of immobilised water depends on the method used. Consequently, WHC must be defined in terms of the method of measurement. In most of the methods for determination of WHC, the loose water is released by pressing the sample between two plates (e.g. "filter-paper press method") or by centrifugation.

The filter-paper press methods and certain centrifugation procedures can be used for the measurement of WHC in the evaluation of meat quality. Centrifugation methods are probably more accurate and reproduceable than the press methods but they can be hardly used in the slaughter house. A new method for evaluation of WHC - the capillary volumeter method of Hofmann - could be employed also in the slaughter house since it is rapid, accurate and does not need weighing of the sample.

Introduction

The differences in water-holding capacity (WHC) between different meat samples as well as the remarkable changes in WHC during storage and processing of meat are determined by the extent to which the non-tightly bound water (non-hydration water) is immobilised within the microstructure of tissue. There seems to be a continuous transition from the water strongly immobilised within the tissue, which can be expressed with difficulty, to the "loose" water, which can be squeezed out by very low pressure. It is not possible, therefore, to get any absolute figures for the immobilised part of water because the determined amount of immobilised water depends on the method used. Consequently, we must define WHC in terms of the method of measurement (Hamm,1960,1972).

In most of the methods for determination of WHC, the loose water is released by application of pressure, which is produced either by centrifugation or pressing the sample between two plates. For the objective evaluation of meat quality on carcasses only rapid methods are suitable which allow a large series of measurements to be taken.The required size of meat sample has to be small in order to avoid carcass damage. The method should not require mincing or homogenising or heating of the sample, because such procedures are time-consuming and can hardly be carried out in a slaughter house.

According to our experience, three types of methods can be used for objective meat quality evaluation: (1) The filter-paper press method (FPM), which is widely used; (2) the centrifugation methods (CM); (3) the capillary volumeter method , which was recently developed.

Filter-paper press methods

In the FPM developed by Grau and Hamm (1957) 300 mg of muscle tissue is pressed on filter paper between two Plexiglas plates to a round thin film, and the water squeezed out is adsorbed by the filter paper. The area of the ring of expressed juice adsorbed by the filter paper is proportional to the amount of loose water. Grau and Hamm demonstrated that the pressure produced by screwing the plates by hand is so great that individual differences of pressure do not influence the amount of expressed water. The technique is very simple and can be carried out in a slaughter house. A number of more or less useful modifications of the FPM was suggested; in most of them the application of a defined pressure was recommended (Hamm,1972). The accuracy of this method is satisfactory provided that the time of weighing the sample on the filter paper is short enough. The coefficient of repeatability reported in the literature varies from 0.68 to 0.98 (Engelke,1961, Fewson and Kirsammer,1960; Fewson et al.,1964; Gravert,1962; Janicki and Walczak,1954; Sonn,1964). The variance of error found by Fewson et al. (1964) was smaller than 5 %.

Centrifugation methods.

In most of the suggested centrifugation procedures for measuring WHC of meat the samples are minced or homogenised. If muscle pieces are used, heating of the sample is most often recommended in order to provide the release of a measurable amount of juice (Hamm,1972). In our opinion, the method of Bouton et al.(1971,1972) represents a reasonable centrifugation procedure, avoiding mincing and heating. In this method, a weighed muscle sample (3-4 g) is centrifuged at 100 000 x g for 1 hour in stainless steel tubes. We found that with centrifugation also at 60 000 x g for 30 min good results are obtained. The juice expressed from the meat is decanted off. The meat sample is removed from the tube with forceps, dried with paper tissue and then reweighed to determine liquid loss. The coefficient of variation is better than 5 %; and although the conditions are arbitrary they are easily reproduceable.

Highly significant correlations between the results of different centrifugation methods (CM) and FPM were found (Brendl and Klein,1971; Engelke, 1961; Holtz,1966; Janicki and Walczak,1954; Sonn,1964).Goutefongea (1963, 1966) reported that both his modification of the FPM (with 5 g samples), and a CM showed the same variability and that the FPM records small differences in WHC better than the CM. Other authors, using smaller samples for the FPM (0.3 - 0.5 g) came to the conclusion that the CM is more exact and more reproduceable(Gravert,1962; Janicki and Walczak,1954; Steinhauf et al.,1965). This might be mainly due to the larger size of samples used in the CM.

The CM of Bouton et al.(1972) is reliable and relatively easy to perform. But it needs - as all CMS- larger meat samples and more time than the FPM. The need of a high-speed centrifuge makes it almost impossible to use this type of method in a slaughter house.

Capillary volumeter method.

A completely new type of method for the evaluation of WHC of meat is based on the application of capillary forces to the muscle tissue. This method was developed by Dr. K. Hofmann in our laboratory (Hofmann,1975). A gypsum (plaster of paris) diaphragm is placed on the surface of the intact tissue with a relatively low pressure (load of 800 g) for a definite time (30-120 sec). The loosely bound water is sucked up into the diaphragm by the effect of capillary forces. The air displaced from the capillaries by the meat juice goes into a U-shaped calibrated glass tube, containing a coloured fluid (Fig. 1). The volume of the displaced air, read from the shift of this fluid, is equal to the volume of loose water and is inversely proportional to the WHC of the tissue.

The preparation of the gypsum diaphragm has to be carried out under standardized conditions, but fortunately the porosity of the diaphragm is not influenced by the source from which the gypsum is obtained. It is not necessary to adjust the diaphragm to a certain humidity. For each measurement a new diaphragm has to be used, but this is no problem due to the very low price of gypsum. The thickness of meat has no influence on the results obtained. However, the volume of loose water sucked up by the diaphragm depends on the pressure used. This volume increases with an increase in load to about 300 g (Fig. 2). Then a plateau follows, i.e. no further uptake of water by the diaphragm occurs. At loads higher than 1000 g the volume increases again with rising weight. In the low-pressure range of these curves the capillary forces are dominating. Between 300 and 1000 g the capillary forces seem to be equal to the WHC of the tissue; at loads higher than 1000 g meat juice is squeezed out by the high pressure. From these curves it can be concluded that at a load of 800 g small variations in pressure have no influence on the results (Fischer and Hofmann,1975).

The method, called the capillary volumeter method (CVM) is highly reproduceable. The coefficient of variation was found to be about 4 %, regardless whether the time of measurement was 10, 30, 60 or 120 seconds. Pressure can be applied also by employing a spring instead of weights (Fischer and Hofmann,1975). Using this principle of measurement, it should be possible to measure WHC of meat directly on the carcass without removing a sample of tissue. Such a design is under development.*

A significant correlation between the results of the CVM and the results of the CM of Bouton et al.(1972) was found (Table I). The correlation between the CVM and the FPM (Grau and Hamm,1957) was smaller but still significant (Table I). We used the CVM successfully for the evaluation of the quality of normal and PSE pork.

Table I. Correlations between the results of the Capillary Volumeter Method (CVM)(Hofmann,1975) and the results of the filter-paper press method (FPM)(Grau and Hamm,1957) and of a centrifugation method (CM)(Bouton et al.,1972)
(CVM:µl loose water; FPM:cm^2 area of loose water;
CM:bound water related to total water).

Time of measurement (CVM)	CM/CVM	FPM/CVM
60 seconds	n = 60 r = -0.77 P < 0.1	n = 94 r = 0.56 P = < 0.1
120 seconds	n = 60 r = -0.82 P < 0.1	n = 94 r = 0.62 P < 0.1

The CVM has the following advantages: (a) no weighing of samples required; (b) easy to handle; (c) highly reproduceable; (d) rapid (measurement within 30 sec);(e) the read value represents the result; calculations are not necessary; (f) direct measurement at the carcass is possible in principle.

It should be mentioned that the CVM only gives information on relative differences in the amount of "loose water" but not on the WHC of meat i.e. on the amount of water bound by unit weight of tissue or dry matter or protein. However, the CVM reflects quite well differences in WHC between different meat samples provided that the meat has not lost remarkable

*A patent applied for

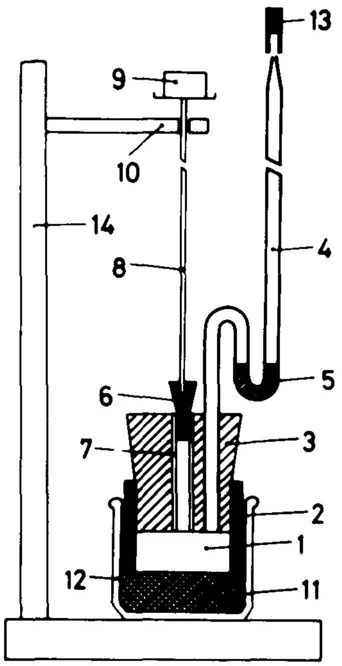

Figure 1

Capillary Volumeter.
1: Porous gypsum disk; 2: plastic ring; 3: silicon stopper; 4: calibrated glass tube; 5: coloured fluid; 6: stopper; 7: glass tube; 8: rod; 9: weight; 10: holding device; 11: meat sample; 12: weighing jar; 13: closing cap; 14: stand (Hofmann, 1975)

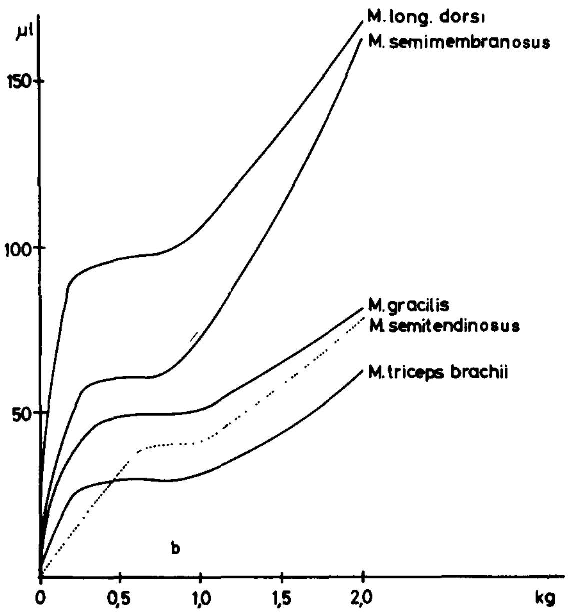

Figure 2

Influence of load (kg) on the volume (µl) read at the capillary volumeter (Fisher and Hofmann, 1975) amounts of moisture by evaporation during storage after slaughter. Here the same situation exists as in the widely used FPM which measures the "area of loose water" only and not the WHC which also requires the determination of the total moisture in the meat sample.

In the future the CVM possibly will replace the FPM and the CM in the objective evaluation of meat quality.

Conclusions

The filter paper press methods and certain centrifugation procedures can be used for the measurement of WHC in the evaluation of meat quality. Centrifugation methods are probably more accurate and reproduceable than the press methods, but they can hardly be used in the slaughter house. A new method for evaluation of WHC -the capillary volumeter method of Hofmann - could be employed in the slaughter house since it is rapid, accurate and does not require weighing of the sample.

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TASTE PANEL TECHNIQUES AND STATISTICS

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Summary

The aim of beef production is an edible commodity, but eating quality is probably the characteristic of beef that is least tractable to scientific research. There seems little prospect of studies on mechanical deformation or gas chromatography being able to predict the consumer's reaction to texture or flavour and the "laboratory type" taste panel has been extensively used to assess differences in eating quality brought about by changes in the factors of production. Reports in the scientific literature of experiments concerned with eating quality of beef extend over a period of 72 years, but during this time there has been no attempt at standardisation of techniques, which is particularly difficult in this field.

Cooking, for example, is a necessary nuisance. Care must be taken to ensure that cooking neither introduces new differences to confuse the effects of the treatments being compared nor removes any differences that might be present, but it is not easy to exercise scientific control over the art of cooking. Standardisation for the sake of increased accuracy necessarily involves loss of applicability and the same thing is true of a number of "consumption variables" that can be added at this stage, which stresses the importance of choosing appropriate statistical methods and paying careful attention to the interaction between design and interpretation.

Attempts to rationalise methodology on an international basis are made more difficult by intranational differences in these consumer variables, but one real advantage has already been seen to accrue from such cooperation. In trying to find exact translations of the terms used in the study of eating quality, experimenters have been forced to think more carefully about what these terms mean, and more precise definition has been of benefit to the concepts themselves. Such a process is particularly necessary and important to this topic.

Introduction

The entire effort of beef production, and its associated scientific research, is wasted if the final product is not eaten. Given that a certain amount of animal protein is necessary, or at least desirable, for human needs the beef animal is probably not the most economic or efficient means of producing it. The continuing existence of a massive trade in beef is therefore due largely to its appeal as a food, and this appeal is mainly sensory. Yet only in recent years has much attention been paid by research scientists to the palatability aspects of food. Though the literature on eating quality of beef goes back some seventy years (Otis, 1903) only since the second world war has the information in the scientific journals been more than a trickle. In spite of the voluminous publications that have appeared more recently (e.g. Drake and Johansson, 1969) it remains true that human sensory reactions to the varying stimuli of an edible commodity are scientifically untractable. Nevertheless there has been considerable progress, and at least a growing awareness of the importance of eating quality.

Some important variables

The investigator who feels that he should include eating quality as one of the characteristics to be assessed on his carcasses, or considers that his experimental treatments may have had an important influence on some aspects of palatability, cannot appeal to any standard method or criterion. He is faced with a number of decisions concerning additional variables that must be taken into account at this stage. Some of the most important of these are:-

(a) What part of the carcass to use. It is clearly impracticable except in very special circumstances, to arrange for all the beef to be consumed, yet the possibility must be faced that the experimental treatments may have affected the palatability of only those parts that are excluded at this stage.

(b) How to cook the samples. The large variety of methods available will be limited partly by the decision taken at (a), but will not be completely determined by it.

(c) How to present the samples to the tasters. Even accepting the obvious principle that the beef should be presented without addition of other foods, there are many possibilities, such as whether to use hot or cold meat.

(d) How many tasters to use. Opinions differ amongst experienced workers about the optimum number of people to form a taste-panel, and there are many ways of selecting them.

(e) What particular characteristics (appearance, colour, flavour, tenderness, juiciness etc.) to assess, and what concomitant measurements to take.

(f) What method of quantifying the tasters' responses to adopt. Direct difference tests, dilution tests, profile methods, ranking, scoring, magnitude estimation and chew-counts have all been employed by workers in this field (see e.g. Amerine, Pangborn and Roessler, 1965).

(g) How to analyse the results. To a large extent the statistical methods used should depend upon the decisions taken about the preceding questions, but the investigator usually finds that a variety of analyses is still possible.

To cover the issues raised by these questions at all adequately, the investigator finds that he has to enlarge his experiment inordinately. Alternatively, by choosing some particular combination that appeals to him, he is open to the charge that his conclusions are of limited applicability. In a paper of this length one cannot hope to discuss these difficulties in any detail, so one of them - (b) cooking - will be considered in rather more depth, though not fully, in order to illustrate the issues involved.

Cooking

Some form of cooking is essential, but from many points of view, it is an interference of great nuisance value. The investigator wants only to present the meat to the tasters without change, but any cook knows that it is possible to improve the palatability of poor meat by good cooking, and certainly easy to ruin good meat by bad cooking. Cooking is still an art that has attracted little scientific research in its own right. The investigator therefore has to be particularly careful to ensure that cooking neither introduces new differences to confuse the effects of the treatments being compared, nor removes any differences that might otherwise be apparent. Rigid standardisation of the cooking process has therefore been adopted by most research workers. However, a further choice is now available. The investigator may either cook the meat for a standard time - or a standard time per unit weight - or cook it until it reaches a predetermined temperature. He cannot do both, and most investigators have adopted the latter alternative because of the greater degree of control that can be exercised.

Methods of cooking beef can be classified according to whether hot air, water, steam, or fat is used, but the most common method adopted by experienced workers is roasting (hot air) probably because this lends itself more readily to scientific control. A "boil in the bag" (water) method has also been used, usually on a laboratory scale, but some workers feel that this is too far removed from common household practice. Microwave cooking offers interesting possibilities but it has generally been found that the differential heating of lean and fat raises too many problems.

However, describing a cooking process in these terms is not the same as defining it for scientific purposes. If, for example, the investigator decides to roast his samples, following the majority of experienced workers (probably more often than is justified by the proportion of a carcass that is normally roasted by the housewife) and that he also decides to control and standardise the temperature rather than the time of cooking, he is still faced with such questions as:- what should the final temperature be? what is the best oven temperature (i.e. rate of cooking)? and should the latter be constant? In general, the lower the cooking temperature the more evenly cooked is the meat, but there is a danger that if heated at too low a temperature for too long, all samples might be cooked to characterless uniformity. Workers in America have used oven temperatures as low as 110°C and as high as 260°C. Higher oven temperatures tend to preserve flavour, but what really matters to the investigator is that discrimination and consistency of scoring by the panel members should be as high as possible, and though too little work has been done on this subject, it seems that high oven temperatures lead to inconsistent results, possibly because the joints are not evenly cooked.

In spite of strict temperature control it has been found by many workers (Cover et al, 1957, Harries et al, 1963) that the degree to which the meat is cooked, as judged visually, can still vary. So can the speed with which it reaches its final temperature. The investigator is therefore able at this point to measure instrumentally, and assess sensorially, several characteristics (heating curves, weight loss, "degree of doneness") that may tell him more about the meat, and therefore may reflect differences due to his experimental treatments. The measurement of thermal conductivity by physical means does not seem to be very satisfactory, probably because of the heterogeneous nature of beef, and measurements for a whole joint, collected as an incidental part of the cooking process, have usually been used instead. But such measurements,described as concomitant in (e) above, add to the complexity of the experimental results. For example, it was found in a series of such data, gathered over many years (Harries et al, 1963) that when rib roasts of beef, all within ± 220 g of 1.36 kg initial weight were cooked to an internal temperature of 71°C in ovens at a constant temperature of 149°C the time required per unit initial weight varied from 5 min/100 g to 22 min/100 g with an average of 12 min/100 g. In view of this enormous range, it is surprising that most popular cook books still recommend, for roasting beef, a standard time per unit weight. Further details of some of these problems will be found, e.g. in Harries et al (1960) or in a review of the subject by Tilgner (1964).

Texture

One of the problems is that cooking itself affects the texture of beef, which is the most important of its sensory attributes. It is well known that heating toughens myofibrillar proteins and tenderizes collagen. The relative amounts of connective tissue in a piece of beef will therefore partly determine the optimum cooking method. The biochemical reactions that occur during cooking are complex and not entirely understood. According to Laakkonen (1973) who reviewed the factors affecting tenderness during the heating of meat, physiological maturity, fat content, enzymes, pH, post mortem age and contraction state, moisture binding capacity, behaviour of proteins during heating, rate of temperature rise, and method of heating are all involved in determining the characteristics of the cooked product. The investigator interested in eating quality is therefore faced by the dilemma that if he knew all about his beef he would know how to cook it, but he must cook it before he can decide how tender it is, because the final arbiter of texture can only be the human mouth, in the present stage of knowledge. Though an immense amount of work has been done on the mechanical properties of muscle, studies of instrumental deformation have in general shown that only 50% of the variation in texture can be so explained.

One of the features of this work is its fractionation. Specialists in each area work to try and establish relationships between texture and the factors concerned in their own particular system, frequently using correlation techniques that are quite inadequate for the purpose. Since, as Laakkonen suggests, all the above factors are involved, with complex interrelationships between them, then only an extensive investigation using multivariate statistical techniques can resolve the problem, and answer some of the questions with which Laakkonen concludes his review. The area of physical and chemical determinants of texture of beef seems to be particularly tardy in exploiting the power of the newer types of statistical analyses.

Multivariate statistical techniques have, however, been used with some success in the more diffuse and difficult area of the sensory assessment of texture. For instance, a series of papers by Yoshikawa, Nishimaru, Tashiro, and Yoshida (1970) used factor analysis to attempt a classification of 40 words used to describe the texture of 79 foods with the purpose of identifying the important attributes of sensory mouth-feel. Reviews by Szczesniak (1963), Kramer and Szczesniak (1973) and others illustrate the attention being paid to the problem from the opposite point of view - that of attempting to classify and simplify sensory textural attributes in order to study them more effectively. Thus Harries, Rhodes and Chrystall (1972) for example used a factor analysis to attempt such a simplification and found that two main factors, described as "toughness - tenderness" and "juiciness" accounted for 95% of the total variability. More recently, Howard (1974) also using multivariate techniques for a somewhat different purpose, has incidentally found that a third component which he calls "elasticity" is necessary. Thus a brief consideration of only one of the extra variables that have to be taken into account when thinking of the eating quality of beef, illustrates the fact that no one of the seven groups of factors listed in the introduction can be examined in isolation. They are interrelated in complex ways. A great deal of progress has been achieved during the last thirty years, but an outstanding conclusion is that much more research is needed into the methodology of sensory analysis. Most workers seeking to advance the subject for its own sake, have understandably avoided beef as a test material, because of its inherent variability.

Variability is also apparent intranationally in domestic practice, which does not facilitate international agreement on methodology. An investigator cannot possibly take account of regional differences in the way beef is prepared for consumption when deciding on some standard method for comparing experimental treatments, and is therefore open to the charge that his conclusions are not necessarily valid for all parts of his own country. However, the adoption of some standard, simple method of preparing samples for sensory analysis is no more artificial compared with lay practice, than numerous other methods used in research, and the achievement of an internationally agreed technique should not be held up on this account.

The Vocabulary of Sensory Analysis

The topic of the vocabulary of eating quality is particularly important from the point of view of international collaboration, the main theme of this seminar. Before a methodology can be agreed upon, each participant must understand what the others mean by the words they use. Over the last few years, several countries have been working towards a better definition of the terms used in sensory assessment, and a British Standard (BS 5098:1975) Glossary of terms relating to sensory analysis of food has already been issued. French and German standards are in preparation, and the definitions proposed by le Magnen (1964) have been extensively quoted. The British version includes French equivalents where these are available and many of the terms defined have also been accepted internationally by the working group of the International Standards Organisation charged with the task of achieving international agreement about sensory analysis of agricultural food products. It is interesting to note that many terms relating to texture however, are listed at the end of the British Standard as not having yet been defined; nor have any words describing the different forms of cooking, for obvious reasons. The work of these committees and working groups, both national and international, continues towards standardisation of the whole methodology of sensory analysis, including the definition of further terms. Jowitt (1974) proposed a list of definitions of words to describe textural attributes, for discussion. One interesting feature of the discussions taking place during production of these standards is that in order to attain exact translations of the terms used, experienced workers have been forced to think more carefully about what the terms mean, resulting in some cases in more precise ideas about the concepts themselves. Such a process can only be of advantage in the progressive rationalisation of sensory methodology.

Conclusion

The fact that this subject has not yet been crystallised into standard methods is probably an advantage from the point of view of international cooperation. There are few textbooks that lay down tenets and precepts; there is no accepted hard core of knowledge that the beginner must master as in the major scientific disciplines before he can start experimenting in the subject. This should mean that those laboratories where work on sensory assessment is being done might be more flexible in their outlook and be more ready to adopt some agreed international method. Attempts to forge such standards, however, must cover all the difficulties listed earlier in this paper. The subject of sensory assessment has now become complex, and experienced research workers will know that invalid and indeed nonsensical results can easily be obtained if sufficient care is not devoted to the many issues involved in studying eating quality. Though this area

On the other hand, the problems involved have been solved very successfully by a number of research workers, and the old distinction between "subjective" and "objective" methods is no longer helpful. It has been shown many times by interchange of samples amongst laboratories that so-called objective methods may not be as accurate or reproducible as they are supposed to be, whilst an objective approach on the part of an investigator towards the study of eating quality can result in scientifically valid conclusions. The methods of sensory assessment are those of the bio-assay (Harries, 1955); the investigator uses the responses of organisms to the sensations aroused by the samples to draw conclusions about the stimuli that generated them, and an objective studious approach is called for during planning and interpretation. Though this area of research is difficult it must be remembered that some knowledge of the effect of production variables on consumer appeal is vital to the successful application of the results of scientific research.

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FACTORS IN BEEF QUALITY

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Abstract

Two recent investigations are briefly described. Four age-groups of commercially slaughtered bulls and steers were compared for long. dorsi meat quality, and though bulls' meat was found to be generally tougher than steers' meat within the same group, between-groups relations were not consistent. The second investigation, of the effects of slow chilling, tenderstretch suspension and post-mortem aging on meat quality showed that chilling rate had a considerable influence on long. dorsi meat tenderness. This could probably account for between-group inconsistency in the bull beef experiment. Tenderstretch suspension achieves a large increase in tenderness in the long. dorsi and would be currently recommended for factory use coupled with the seven days aging that is normal for Irish beef in transit. The interrelations of various causal factors in beef tenderness are briefly discussed.

Introduction

The foundation of the beef trade out of Ireland is the prime young beast that provides top quality roasting and grilling cuts. Meat from such animals must be tender, since it is this quality which governs the price the ultimate consumer will be willing to pay for it.

Certain grilling cuts, such as the fillet (M.psoas major) will always be tender. Other grilling cuts such as the short sirloin (M.longissimus dorsi) and the rump steak (M.glutaeus medius) are generally tender but sometimes tough, topside (M.semimembranosus) is tender to slightly tough and is better roasted than grilled, while silverside (M.biceps femoris and M.semitendinosus) must usually be braised to make it tender. A survey in Dublin has shown that variability in tenderness is the commonest cause of dissatisfaction by the purchaser (Riordan 1972)

The task of our research in fresh beef is thus to show how to reduce variability and guarantee tenderness, and how to increase the marketed amounts of tender meat from given supplies of cattle. This paper will briefly describe some recent work in our laboratory, attempt to relate it to current studies of causal factors in beef quality and indicate possible lines of further advance.

Bull beef

Bulls grow faster than steers and at the same weight are less fat (Harte, 1969). We have assessed the tenderness of meat from four groups of Hereford and Friesian bulls and steers as they became available from production experiments (Joseph and Connolly, 1974).

The cattle were from 402 to 614 kg slaughterweight, at ages of 16, 22, 24 and 25 months. The youngest were finished on grain and silage, the others on pasture. Half of the 22 month group were treated with 'Proten' tenderiser. All were slaughtered and dressed commercially. Post mortem, meat from the long. dorsi, 7-13 rib region, was aged for 7 or 14 days. Tenderness was estimated on cooked meat by a Volodkevich bite-tenderometer and a taste panel (TABLE 1).

TABLE 1 Tenderness of bull and steer beef, ranked by taste panel score

Age in months											
16			22			24			25		
Treatment	Score	Force	Treatment	Score	Force	Treatment	Score	Force	Treatment	Score	Force
			(Friesians)			(Herefords)					
BF 7	2.60	115.34	BNP 7	1.26	80.40	B 7	4.82	49.62	BH 14	3.85	68.80
SH 7	3.43	71.40	BNP14	2.79	62.19	S 7	6.78	31.64	BF 14	3.96	83.08
BH 7	3.43	96.51	SNP14	4.24	42.57				SF 14	4.13	59.97
BH14	3.80	71.79	BP 7	4.74	80.96				SH 14	4.84	46.92
BF14	3.90	87.49	SNP 7	5.36	37.95						
SH14	5.30	59.83	BP 14	5.79	59.53						
SF 7	5.50	61.00	SP 7	6.10	24.36						
SF14	5.87	57.48	SP 14	6.10	27.70						
Least Significant Differences (p 5%)											
Sex, breed Constant:	1.37	22.8	Sex, Proten Constant:	0.77	18.3		0.45	7.60		1.15	21.8
otherwise:	1.78	22.2	otherwise:	1.06	20.9						

B = bull; S = steer; F = Friesian; H = Hereford; 7 = 7 days p.m. 14 = 14 days p.m. P = Proten; NP= Non-Proten

The taste panel scored on a scale from 0 'extremely tough' to 8 'extremely tender'. The tenderometer evaluated maximum force to shear, in Newton, and the results are corrected to a standard cross-section area of 60 mm^2. In general, the meat from the bulls was tougher than that from comparable steers, though the longer aging period and the Proten treatment tenderised it. Neither chronological age within the range nor the breed affected tenderness in any consistent direction. The tenderometer test gave approximate indications of taste panel verdicts, but when fixed treatment effects were eliminated the correlations obtained were very low.

Slow chilling, tenderstretch suspension and *post mortem* aging

This work examined three methods which could be operated in the meat factory for improving tenderness. 27 Hereford-cross heifers with 2 teeth, varying in carcass weight from 160-240 kg were assigned at random to 3 chilling rates - slow, medium and fast. One side of each animal was suspended normally, the other side by the pelvic bone with a hook through the obturator foramen - 'tenderstretching' (Herring *et al*, 1965). Six muscles were removed from the hindquarter at 2 days *post mortem* and each was cut into 3 sections. These were assigned at random to 2, 7 and 14 days total aging *post mortem* in vacuum bags at 0 - 2°C.

TABLE 2 Mean carcass temperatures 10 hours *post mortem* (°C)

	Chilling rate		
Point	Slow	Medium	Fast
Centre of l. dorsi 11/12 rib	21°	18.5°	8°
Centre of round	30°	28.5°	24°

Bacterial growth and shrinkage were examined in the whole carcass. Tenderness, juiciness, flavour, colour and washing and drip losses were examined in the muscle sections. Sarcomere length was also measured at 2 days *post mortem*.

The *long.dorsi* (TABLE 3) was toughened considerably by fast chilling. Tenderstretching reduced this toughening. After 7 days aging, normal and tenderstretched meat had tenderised, but tenderstretched *l.dorsi* was still one score unit more tender. Slow and medium chilled meat was more tender still, if tenderstretched,

TABLE 3 Chilling, suspension and aging effects on tenderness in <u>M.longissimus dorsi</u>, shown by taste panel scores and shear force (Newton, at 100 mm^2 cross-section)

		Total aging period post-mortem					
		2 days		7 days		14 days	
Chilling rate	Suspension	Score	Force	Score	Force	Score	Force
Slow	Tenderstretch	5.17	72.89	5.43	62.56	6.04	58.84
	Normal	4.51	96.43	5.17	76.73	5.25	75.18
Medium	Tenderstretch	4.76	77.36	5.84	60.75	5.68	51.75
	Normal	4.65	92.39	5.19	70.82	5.40	58.53
Fast	Tenderstretch	3.65	97.73	5.38	66.14	5.59	60.47
	Normal	2.40	140.66	4.43	92.31	4.52	82.04

Least Significant Differences,		Score	Force
	chilling rate and suspension constant :	0.81	14.21 (N)
	chilling rate only constant :	0.76	15.74 (N)
	All other comparisons :	1.06	23.59 (N)

at 7 days, but since we found bacterial growth and carcass weight loss to be reduced by fast chilling, we would recommend fast chilling and tenderstretching to our factories. The carcasses must be cut up in the factory before shipping.

Psoas showed no chilling effect, but a slight toughening from a score of 6.9 to 6.4 in the centre due to tenderstretch suspension because this muscle is on the inside of the hip. A small aging effect was detected by the shear meter. The biceps femoris under tenderstretch improved significantly from a score of 2.81 to 3.13, which is still probably too tough for grilling. The semitendinosus showed no change in taste panel score under any of the three treatments. The mean score was 3.64, indicating that it is also probably too tough to grill.

Semimembranosus. Tenderstretching and aging for 7 days both increased tenderness. At 7 days tenderstretched meat scored about 4.2, significantly more than normally suspended meat, which scored about 3.3. Chilling rates had no effect. Glutaeus medius was improved slightly but significantly by tenderstretching and aging. At 14 days tenderstretched meat scored about 5.44; at 7 days normally suspended meat scored about 4.84.

Some small changes in juiciness, flavour, colour and cooking and drip losses were found to result from the different treatments. These were considered to be unimportant. Sarcomere lengths were increased by tenderstretching, except in the psoas. No effect due to different chilling rates was detected.

TABLE 4 Mean sarcomere lengths in normal and tenderstretched muscle (μM)

	long. dorsi	psoas	b.femoris	s.tendinosus	s.mbranosus	g.medius
TS	2.31	2.57	2.73	2.34	2.64	2.48
Normal	1.80	3.18	1.83	2.05	1.80	1.73

(All differences were significant)

Discussion

Bull meat has been shown to be tougher than steer meat by a number of authors (Bryce-Jones, 1969; Martin et al, 1971; Sumwalt et al, 1964; Bailey et al, 1966). Price (1971) found 8-11 month old bulls to be tougher than control steers, but indistinguishable in older animals of up to 21 months. Chrystall (1971) recorded that bulls were less acceptable than steers but that variation within sexes was often greater than between sexes.

The present work shows long.dorsi meat from bulls to be tougher than that from steers. TABLE 1 has 11 logical contrasts of bull versus steer. Bulls are significantly tougher in seven contrasts, tougher (non-significantly) in three and equally tough in one. However the absolute taste panel score for bulls (or steers) in one age group is not a good guide to the score in other groups.

Similarly there are eight logical contrasts of 7 versus 14 days aging in Groups 1 and 2. In 3 contrasts 7 day aged meat is significantly tougher than 14 day aged meat; in a further 3 it is tougher (non-significantly); in one contrast it is the same, and in one contrast it is significantly more tender. Again, the absolute score for 7 (or 14) day aged meat in one group is not a reliable guide to the score in the other groups.

It seems therefore, that effects due to sex and aging, reasonably consistent in their interrelations within any one age group vary between groups, perhaps because of some background value, that is steady within a group but varies between groups. The cause of this is not likely to be chronological age (operating through increased collagen cross-linking (Hill, 1966)) since there is no directional drift in the scores with chronological age. As the cattle were slaughtered commercially in groups, variations in conditions at slaughter are probably the cause of the varying background value.

TABLE 3 shows that long.dorsi from fast chilled, normally suspended carcasses is tougher by the taste panel's score and requires a higher shear force than the same muscle from slow or medium chilled carcasses. This effect persists to 7 and 14 days. It is consistent and large enough to provide an explanation for the inter-group variation found in the bull beef experiment. We have found (unpublished observations) that commercial chilling varies in the rate at which particular carcass temperatures are brought down. The size of a carcass, its position in the chill and the load of the chill all seem to be important.

This underlines the importance of chilling procedure as a causal factor in meat quality. Its effects should be evaluated in conjunction with those of chronological age, sex, breed, aging post mortem.

Toughness due to rapid post mortem chilling in red muscle is thought to be due to shortening of sarcomeres triggered by concentrations of Ca^{2+} in excess of pCa 6.4 - 6.5 (Davey and Gilbert, 1974), arising from the failure of sarcoplasmic reticulum disorganised by cold, to resorb Ca^{2+} released from mitochondria affected by the post mortem anoxic milieu within the fibre. (Buege and Marsh, 1975).

Cold shortening has been experimentally demonstrated in unrestrained beef muscles sternomandibularis, psoas and long.dorsi (Locker and Haggard, 1963). The consequential toughening has been demonstrated by Marsh and Leet (1966) in excised beef sternomandibularis and excised lamb long.dorsi. Marsh et al (1968) demonstrated cold induced toughening on lamb long.dorsi left on the carcass, and Taylor et al (1972) have reported the shortening of sarcomeres in the lamb long. dorsi left on the carcass, associated with the toughening provoked by rapid chilling.

Smith et al (1971) chilled beef carcasses under normal commercial conditions at 2°C and compared the toughness and sarcomere length of the long.dorsi after one week with meat from carcasses that had been stored for 16 or 20 h at 16°C post slaughter before being chilled at 2°C and aged. The rapidly chilled meat was much tougher. The sarcomere lengths were not significantly different from those in the slowly chilled meat, and the authors suggest that cold shortening is not likely to occur in beef long.dorsi left on the carcass unless it is exposed to blast freezer temperatures. They attribute the greater tenderness of the slowly chilled meat to the earlier onset of 'proteolysis.'

Parrish et al (1973) found that storage of carcasses at 16°C for 24 h produced long.dorsi meat that was significantly more tender than meat stored at 2°C. The meat was compared at 1 day post mortem (and subsequently at 3 and 7 days). The sarcomere lengths were 1.95 ± 0.03 µm from storage at 2°C and 2.02 ± 0.04 µm from storage at 16°C. They suggest that the insulation of fat cover and muscle mass in the beef long.dorsi on the carcass prevents cold shortening and they attribute the enhanced tenderness of meat stored at 16°C to the greater fragmentation of the sarcomeres, that is, the 'proteolysis' referred to by Smith et al (1971).

Smith et al (1973) obtained enhanced tenderness in long.dorsi stored on the carcass for 20 h at 16°C, followed by 28 h at 2°C; the sarcomere length was 1.7 µm, that of the control stored 48 h at 2°C was 1.6 µm. Tenderstretch suspension further enhanced tenderness and increased sarcomere length to 2.3 and 2.2 µm.

Hostetler et al (1975) reported on the effects of slow chilling and tenderstretch suspension on nine beef muscles from carcasses aged 7 days. Different chilling rates had no significant effect on sarcomere lengths, nor on taste panel scores, at 7 days, but slowly chilled meat gave lower shear force values. Tenderstretch suspension gave significantly longer sarcomeres in the five muscles (LD, BF, ST, SM, GM) recorded in our results. It also produced significantly more tender meat by taste panel score in the long.dorsi, semimembranosus and glutaeus medius, and in bulls only, biceps femoris. The psoas was slightly toughened.

It appears from the work of other authors that chilling at 2°C does not produce cold shortening to any great extent in beef long.dorsi left on the carcass. We did not detect any significant shortening of sarcomeres. Tenderstretching lengthens the sarcomeres and enhances tenderness. Slow and medium chilling, which we found to enhance tenderness in the long.dorsi, even at 2 days post mortem presumably act by allowing the 'aging' or 'proteolytic' process (fragmentation) to commence much earlier and perhaps at an increased rate than would be the case under fast chilling. The Ca^{2+} activated sarcoplasmic factor "CASF" of Busch et al (1972) is probably responsible for this (Penny et al, 1974). After 7 days aging tenderstretched l.dorsi is still more tender than l.dorsi from normally suspended carcasses, whether fast or slowly chilled. Sarcomere lengthening through tenderstretching and fragmentation through aging are clearly to some degree additive in their effects on tenderness, measured by taste panel or shear meter.

The toughness-tenderness parameter can now be related with some confidence to muscle ultrastructure. Marsh and Carse (1974) have shown how the effect on tenderness of sarcomere length changes varies with absolute length. Rowe (1974) has argued that sarcomere length changes also alter the amount of collagen in a given volume of muscle and thus vary the baseline toughness, which has been thought hitherto to be independent of myofibrillar toughness.

It still remains however to work out the effect of post mortem glycolysis and Ca^{2+} metabolism on the cold shortening phenomenon and on the activity of the CASF. Although much of the work quoted here, including our own, has been conceived in practical terms to aid the meat industry, it has thrown up interesting theoretical questions. The commercial development of a meat trade oriented to the quantity production of reliable tender grilling steak will be greatly facilitated by an understanding of the causal factors involved in beef quality.

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DETERMINATION OF MEAT QUALITY IN CATTLE

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Abstract

In beef production experiments the necessary conditions to produce meat quality results of relevance are:

1) The availability of suitable methods for measuring meat quality characteristics.
2) The existence of procedures for handling the animals during transport and slaughter, as well as for the treatment of carcasses and meat samples during chilling and ageing. These procedures should be chosen so that the uncontrolled influence of these factors on meat quality is minimized.

This paper describes some of the investigations and experiences on which the procedures and methods used in meat quality determinations on cattle from Danish research projects are based.

Introduction

This paper contains some comments on the choice of procedures and methods used in the determination of meat quality in cattle from Danish national research projects. It is the hope that these comments will contribute to a discussion not only about which methods should be used in meat quality determinations, but also about the necessity of establishing procedures for the handling of the animals during transport and slaughter, as well as procedures for the treatment of the carcasses and meat samples during chilling and ageing.

Development of standardized procedures

First of all, it is essential to try to ensure that the meat quality results obtained reflect the actual factors being investigated in beef production experiments instead of being results of incidental happenings from the time that the animal leaves the experimental farm until the meat samples are analysed.

To do so it is necessary:

1) to try to decide which factors during transport, slaughter, chilling and ageing influence meat quality.

2) to undertake experiments to establish how the meat quality is actually influenced by each of these factors.
3) to choose procedures which are relevant to those used in common practice and which at the same time ensure that minor and unavoidable variations e.g. in the temperatures and times chosen do not cause major alterations in the meat quality.

To set up such procedures is a difficult and never-ending task. In the following is described some of the experiences and opinions upon which we have based our choice of procedures and methods.

Transport and handling the live animal

Little is known about the influence of transport conditions on the meat quality of beef. Certainly prolonged stresses during transport and stabling at the slaughterhouse can result in increased ultimate pH-values in the meat, especially from calves and young bulls (Buchter, 1970, Freeden et al, 1972). Experimental animals are therefore in our experiments always transported directly from the farm to the slaughterhouse and slaughtered shortly after arrival. Throughout they are tied individually.

Promising results (Khan & Lentz, 1973) indicating a relationship between rate of glycolysis and tenderness have - as far as we know - not been confirmed by other research workers. Beef does, however, show different rates of glycolysis after slaughter, and it is very reasonable to expect that, even if beef animals are not as sensitive as pigs to the handling during transport and immediately before killing, these factors can influence the development of glycolytic processes especially in young animals.

In relation to this we noticed more exudative meat and more frequent haemorrhages in the meat from experimental calves during a period when the slaughterhouse stables were being rebuilt and the animals therefore were let loose in a narrow passage on their way from the provisional lairage to the stunning area.

Slaughter

During the process of slaughter it is theoretically possible that such factors as stunning, dehiding, splitting, washing and method of suspension might influence meat quality. Apart from comparisons between ordinary suspension and suspension from the aitch-bone (Hostetler, 1970), literature on investigations in this area is scarce. Most work on stunning of beef is done in Russia. A recent FSTA abstract (Mitsyk, 1972) indicated that electrical stunning of 300 kg castrated bull calves gave a lower water retention capacity than stunning with a captive bolt pistol. A minor investigation of our own (Buchter, 1970) showed no major effect of the time and method of splitting on meat tenderness.

I have no doubt that the slaughter processes can influence meat quality. However, in a commercial slaughterhouse the methods of slaughtering are strongly standardized, and therefore each animal receives an approximately identical treatment, but, of course, this only applies to a single plant within a limited period of time.

Chilling and cutting up

Chilling conditions do have a major influence on tenderness and water holding capacity.

In a series of experiments designed to find out which chilling conditions should be used for experimental animals (Buchter, 1970), it was established that for 250 kg calves temperatures in the chilling room should be as high as 10°C if cold shortening in the longissimus dorsi muscle is to be avoided. This was an unacceptably high temperature from a commercial point of view. As a compromise it was decided to use 6°C, although chilling at this temperature does cause some toughening in about 30% of the calves. A further series of experiments with 450 kg young bulls showed that with these animals only little cold shortening occurs at 6°C possibly due to the greater volume of muscles. In the experiments with young bulls the variation in tenderness along the longissimus dorsi muscle was investigated at different temperatures (Buchter, 1972). The results showed considerable and uneven variations in tenderness along the muscle when the chilling temperature was decreased to 4°C and below.

By choosing 6°C in the chilling room for the first 24 hours post mortem, the effects of cold shortening are under control, but they are still present especially for smaller animals. It is therefore often necessary to build special chilling rooms, as we have done, where the experimental animals can be chilled at more controlled temperature and airflow conditions than can be obtained in commercial chillers.

The above chosen chilling conditions might not be optimal for larger and fatter animals, where the rather slow chilling rate can result in the occurence of "PSE" - meat in the deep thigh muscles.

The day after slaughter the temperature in the chilling rooms is decreased to 4°C. At this point the rigor processes have advanced so far that no further cold shortening can be expected as long as the muscles are left intact on the skeleton. However, if the muscles are cut out, serious toughening of the longissimus dorsi muscle will occur (Buchter, 1970). The cutting up of the carcasses should, therefore, not take place before 48 hours, post mortem at the earliest.

Ageing

The ageing processes should be allowed to finish before the meat quality is determined. According to our experiences little or no further increase in tenderness can be expected after the meat has been aged at 4°C for the following periods of time (Buchter, 1970, Buchter, 1972):

4-5 days post mortem for l. dorsi muscle from 250 kg calves
8-10 days post mortem for l. dorsi muscle from 450 kg young bulls
14 days post mortem for l. dorsi muscle from 1½-3 years old beef carcasses.

Choice of muscles

According to traditional practice meat quality investigations are often carried out on the longissimus dorsi muscle. This muscle is one of the commercially important cuts, on which the customers themselves often perform a certain evaluation, first of the appearance of the raw meat and later of the flavour and tenderness after cooking. From an experimental point of view the longissimus dorsi muscle has the advantage of being relatively uniform and the sampling position can be defined exactly by indicating the adjacent vertebrae.

Meat quality varies from muscle to muscle within an animal and it is therefore only to be expected that one single muscle cannot be representative of the whole animal under all circumstances. In several experiments we have investigated the meat quality in one or more muscles besides the l. dorsi. The muscles we have most frequently used are semitendinosus, triceps brachii, biceps femoris and semimembranosus. As opposed to the longissimus dorsi muscle, the influence of the chilling conditions used is negligible on these cuts. From our experience the following comments can be made:

1) In beef production experiments dealing with animals of the same age, sex and breed the results of determinations on l. dorsi of meat colour, % fat, % N, % dry matter and cooked flavour can be considered as "representative" of the whole carcass.

2) The tenderness of the longissimus dorsi muscle is so important per se that it should be determined in all experiments.

3) In experiments dealing with animals of different breeds, sex and age the meat tenderness and if possible also other meat quality properties should be determined on at least one more muscle besides the longissimus dorsi. For this purpose we have obtained good results with the semitendinosus and triceps brachii muscles, while the semimembranosus and biceps femoris muscles seem to be more difficult to use for meat quality determinations.

Choice of analyses

Important factors to consider in determining meat quality is the appearance and juice-binding capacity of the fresh meat, the intramuscular fat content and the flavour and tenderness of the cooked meat.

The analytical methods available to determine these properties are few and seldom "perfect". It is difficult to translate the impressions received by the human eye and mouth into well-defined qualities that can be measured physically or chemically. Further difficulties come from the often considerable variation in meat quality even within the same muscle.

One of the properties that can be measured using reasonably satisfactory methods is meat colour. Complete reflectance spectra and calculation of the CIE-co-ordinates can be obtained with modern instruments.

For most experiments more simple methods will suffice as long as the measurements cover a representative surface area. For darker beef we find our measurements of a single wavelength band using filters (Elrepho-instrument) too insensitive, so for this reason and others, we supplement our colour measurements with a chemical determination of total pigments.

The importance of good juice-retaining capacity is increasing as more and more meat is being stored and sold in smaller cuts. For a number of years we used a modification of the Grau-Hamm press method in beef production experiments, but abandoned it because we often felt insecure about the possible influence on the results of unavoidable technological and analytical variations. As an alternative method we measured the drip lost from the meat samples while they were ageing. Although the sample size in this method is more satisfactory, the problems about the influence of technological factors are still to be investigated and solved.

pH-measurements are undertaken in order to ensure that all meat samples have normal ultimate pH-value. Meat quality results from meat having ultimate pH-values $\geq$ 5.8 are omitted from calculations in our work.

Our chemical analyses might include determination of % fat, % N after Kjeldahl, % dry matter and total pigment. Of these the determination of % fat is the most important. We use the Schmid-Bondzynski-Ratzlaff method as this allows a larger number of samples to be analysed at the same time. According to our experience the variation found in % N in beef production experiments is rather small, and analysis for % N is therefore only undertaken in very thorough investigations.

The most important property is meat tenderness and this is probably also the one that is most difficult to measure by an objective method.

The method we use is based on the Volodkewich principle (Grünewald, 1957), where the meat strips are squeezed between two rounded 20 x 2.5 mm wedges. This method is, according to our experience, well suited to compare differences in toughness caused by alteration in the myofibrils, such as e.g. differences caused by cold shortening or ageing. When the differences in toughness are caused by differences in the amount or the formation of the connective tissue the method seems unfortunately to be more unreliable. For example, we have found in experiments with animals of different ages that even when the taste panel judges the younger animals to be significantly more tender than the older animals, shearforce measurements are often the same.

Until we find better and more reliable methods for objective measurements of meat tenderness the taste panel evaluation is still to be considered as indispensable. Yet at the same time it is necessary to emphasize that taste panel results have a serious limitation in that they cannot generally be used in the comparison of different experiments.

Our two panels each consist of 8-10 housewives who often have great experience in evaluating tenderness, flavour etc. in meat. As for the methods of preparation, samples of the longissimus dorsi muscle are most often fried on a fat-free griddle plate as beef steaks. In a comparison of meat from 120 mature animals of different age and sex we ran two full taste panel evaluations - first one on beef steaks and later one on rare roast beef. The results showed the same pattern. In experiments where more muscles are used, we try to prepare each cut in a different way.

Conclusion

"More knowledge and better methods are necessary".

But time and resources are always limited, and therefore it can only be hoped that the co-operation and pooling of knowledge within this group will result in new suggestions, new facts and more initiative and thus bring all of us to a more advanced status in "the art of determining meat quality in cattle".

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BEEF CARCASS EVALUATION WITH THE 'TEXTUROMETER' REGARDING THE MEAT AGING PERIOD AND BREED *

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Abstract

The purpose of this investigation, carried out on 15 muscles (Table 1) of 40 sides of 4 breeds (5 animals for each breed; Table 2), was to study with the 'texturometer' the effects of three factors (breed, muscle and aging) on some organoleptic characteristics of meat. The observations were carried out on both sides of each carcass, stored at 0-2^{o}C for 9 and 14 days respectively. The more significant results were: (i) all the variables vary statistically within muscle; (ii) the breed is significant within hardness, gumminess, chewiness and adhesiveness; (iii) the aging time was significant within springiness and chewiness; (iv) the interactions among the three factors taken into consideration are not significant; (v) the muscle rank is statistically invariant in relation to breed and aging, thus for confirming the marked histochemical individuality of muscle (Tables 6, 7 and 8); (vi) the analysis of variance indicates that the 'muscle' component is the highest one and within some variables is even higher than 'error' (Table 4); (vii) the range of optimum hanging time tends to vary between muscles and within each quality variable; by prolonging the aging time from 9 to 14 days the meat organoleptic characteristics seem to improve; however, no significant differences were obtained between 9 and 14 days of aging, within muscle and within breed; (viii) these results, while confirming previous studies (Matassino et al., 1974, 1975a), show the practical usefulness of techniques employed in the present study for objective evaluation of carcass characteristics.

Introduction

To improve the evaluation of some qualitative characteristics of commercial beef cuts, the research has been oriented toward methods which would not become obsolete too soon and, at the same time, would give comparable values.

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Objective evaluation would be practically useful to both the breeder and the consumer. As already pointed out (Matassino et al., 1974, 1975a), it is possible to prepare programmes of genetic and technological meat improvement, in order to produce animals which biologically and economically have the qualities requested by the breeder and the consumer. To improve the carcass evaluation it is essential to consider the qualitatively most important cuts and, within these, the most representative muscles. Many researchers have pointed out the importance of several factors affecting aging time: sex, age, marbling grade, nutritional condition, aging temperature, methods of hanging carcass during 'rigor mortis' and type of carcass storage (whole or dissected)(Lehmann, 1907; Hoagland et al., 1917; Steiner, 1939; Bate-Smith, 1948; Harrison et al., 1949; Sleeth et al., 1957 and 1958; Doty and Pierce, 1961; Tuma et al., 1963; Goll et al., 1964; Webb et al., 1964 and 1967; Eisenhut et al., 1965; Herring et al., 1965; Busch et al., 1967; Larmond et al., 1969; Martin et al., 1970 and 1971; Hostetler et al., 1972; Newbold and Harries, 1972).

The aging of the bovine carcass at 0-2^{o}C for 9-14 days (or more) is considered sufficient to obtain cuts supplying meat of sufficient tenderness. Therefore, we have studied aging time as a factor affecting some organoleptic characteristics of meat. In this paper are reported the results obtained at the genetic level.

Materials and Methods

In table 1 are listed the 15 muscles evaluated which belonged to 40 carcasses of 4 breeds (Poland Friesian, PF; German Brown, GB; Italian Friesian 'Cirio', IF_c; Italian Friesian 'Torre in Pietra', IF_t). In Table 2 are reported the averages of some variables at slaughter of 5 animals of each breed taken into consideration in the present study. The methods used are the same already reported by Matassino et al. (1974, 1975a). The reasons to use the 'Texturometer'* are reported by Szczesniak (1963a, b), Brandt et al. (1963), Friedman et al. (1963), Szczesniak et al. (1963), Szczesniak and Torgeson (1965), and Brennan et al. (1975). The considered variables were: hardness, cohesiveness, springiness, gumminess, chewiness and adhesiveness. The meat hanging periods were 9 days for one side and 14 days for the other side of the same carcass, at 0-2^{o}C. To decrease some of the sources of variation, samples of raw meat were used.

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Table 1. The muscles studied and the joints containing them.

Muscle	Symbol	Neapolitan cut
Rhomboideus cervicis	RC	Locena
Trapezius	T	Locena
Triceps brachii, caput laterale	CLaTB	Vacante di spalla
Triceps brachii, caput longum	CLoTB	Vacante di spalla
Supraspinatus	Ss	Lacertiello
Vastus lateralis	VL	Pezza a cannello
Rectus femoris	RF	Pezza a cannello
Tensor fasciae latae	TFL	Pezza a cannello
Gluteus profundus	GP	Colarda
Gluteus medius	GM	Colarda
Gluteobiceps, pars parameralis	PPGb	Colarda
Semitendinosus	St	Girello
Semimembranosus	Sm	Vacante di natica
Longissimus dorsi	LD	Lombata
Psoas major	PM	Filetto

Table 2. Values of some variables at slaughter.

Breed	N	Weight, kg							
		gross live		net live		side			
						days of aging			
						9		14	
		$\bar{x} \pm \sigma$	CV %	$\bar{x} \pm \sigma$	CV %	$\bar{x} \pm \sigma$	CV %	$\bar{x} \pm \sigma$	CV %
PF	5	448.2 ± 24.2	5	402.5 ± 23.3	6	121.5 ± 6.0	5	121.6 ± 6.2	5
GB	5	448.2 ± 12.4	3	409.2 ± 14.8	4	123.6 ± 4.4	4	124.1 ± 5.8	5
IF_c	5	467.6 ± 24.0	5	422.1 ± 22.6	5	123.8 ± 8.8	7	122.9 ± 10.7	9
IF_t	5	492.4 ± 8.7	2	444.7 ± 9.1	2	132.5 ± 3.3	2	131.1 ± 2.9	2

Results and Discussion

Among the three main sources of variation (muscle, aging period and breed), the muscle resulted in statistically significant differences within all the measured variables; the aging period only within springiness and chewiness, the breed within hardness, gumminess, chewiness and adhesiveness; the interactions within all variables were not statistically significant, except A-B interaction (Table 3 and 4) within springiness ($P < 0.01$).

The PF breed gives meat which is less hard and requiring less energy of chewing, after 9 days as well as 14 days of aging (Table 5). These data confirm the importance of breed in affecting texture variables (Matassino et al., 1974, 1975a), the usefulness of methods employed to measure the carcass organoleptic characteristics and genetic improvement.

By varying the aging time from 9 to 14 days, the range of each of the variables varies among breeds: for example, the energy of chewing decreases about 10 per cent within the PF and IF breeds, over 15 per cent within IF_c and about 4 per cent within the GB breed (Table 5). For hardness the differences among the breeds are significant ($P < 0.01$) only for the comparisons PF-IF_t,PF-IF_c and PF-GB, at the 9 days aging level and thus confirming that the range decreases with variation in hanging time.

The results obtained within muscles confirm that the rank values of texturometer variables is invariant in relation to breed (Matassino et al., 1974, 1975a).

Table 3. Results of some statistical analyses.

Variable	F [1]			
	muscle, Mu	aging, A	breed, B	interaction [2] A–B
Hardness	47.0***	2.7	6.3***	0.8
Cohesiveness	9.5***	0.6	1.2	1.0
Springiness	1.9*	4.5*	0.3	4.1**
Gumminess	41.4***	1.4	3.7*	0.9
Chewiness	21.7***	5.9*	3.0*	0.4
Adhesiveness	14.0***	0.3	5.8*	1.5

(1) * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$. (2) Mu–A, Mu–B and Mu–A–B not significant.

Table 4. Variance components and their percentage of the total.

Variable	Component				
	muscle, Mu	aging, A	breed, B	interaction A–B	error
Hardness	52.7	0	1.6	0	45.7
Cohesiveness	17.6	0	0	0	82.4
Springiness	2.1	1.1	0	3.9	92.9
Gumminess	49.8	0	0.9	0	49.3
Chewiness	33.4	1.1	0.9	0	64.6
Adhesiveness	23.9	0	2.4	0	73.7

Table 5. Value (V) of texture variables obtained making = 100 that of breed (B) PF.

Variable											
hardness		cohesiveness		springiness		gumminess		chewiness		adhesiveness	
B	V	B	V	B	V	B	V	B	V	B	V
1. 9 days aging											
IF_t	119.4	IF_t	100.4	IF_c	103.5	IF_t	120.4	IF_c	118.6	PF	100.0
IF_c	113.5	PF	100.0	PF	100.0	IF_c	112.4	IF_t	112.4	IF_c	89.7
GB	110.9	IF_c	99.8	GB	96.4	GB	110.9	GB	105.8	IF_t	71.7
PF	100.0	GB	99.1	IF_t	92.7	PF	100.0	PF	100.0	GB	65.4
2. 14 days aging											
GB	110.4	IF_c	102.2	IF_t	105.9	IF_c	112.1	IF_t	112.6	PF	100.0
IF_t	109.7	PF	100.0	GB	102.1	GB	107.9	IF_c	112.4	IF_t	87.2
IF_c	108.7	IF_t	98.0	PF	100.0	IF_t	107.4	GB	110.7	IF_c	86.0
PF	100.0	GB	96.9	IF_c	99.2	PF	100.0	PF	100.0	GB	64.7
1. and 2. (1)											
IFt_1	119.4	IFc_2	101.8	IFc_1	103.5	IFt_1	120.4	IFc_1	118.6	PF_2	104.5
IFc_1	113.5	IFt_1	100.4	PF_1	100.0	IFc_2	112.5	IFt_1	112.4	PF_1	100.0
GB_1	110.9	PF_1	100.0	IFt_2	98.1	IFc_1	112.4	GB_1	105.8	IFt_2	91.2
GB_2	109.9	IFc_1	99.8	GB_1	96.4	GB_1	110.9	IFt_2	103.5	IFc_2	89.9
IFt_2	109.3	PF_2	99.6	GB_2	94.6	GB_2	108.2	IFc_2	103.3	IFc_1	89.7
IFc	108.2	GB_1	99.1	IFt_1	92.7	IFt_2	107.7	GB_2	101.7	IFt_1	71.7
PF_1^2	100.0	IFt_2	97.6	PF_2	92.6	PF_2	100.3	PF_1	100.0	GB_2	67.7
PF_2	99.6	GB_2	96.5	IFc_2	91.8	PF_1	100.0	PF_2	91.9	GB_1	65.4

(1) Making = 100 PF of 9 days aging.

Table 6. Individual muscle (Mu) values (V) of various texture variables relative to those of the St muscle after 9 days of aging (= 100).

Variable											
hardness		cohesiveness		springiness		gumminess		chewiness		adhesiveness	
Mu	V	Mu	V	Mu	V	Mu	V	Mu	V	Mu	V
CLaTB	144.6	CLaTB	109.9	RF	118.2	CLaTB	161.3	CLaTB	158.5	RF	302.1
CLoTB	120.3	RC	109.3	TFL	109.5	CLoTB	126.1	CLoTB	124.9	TFL	207.7
Sm	101.5	CloTB	103.6	Sm	108.7	RC	103.8	RC	108.6	Sm	187.0
St	100.0	T	102.2	PPGb	108.3	St	100.0	Sm	101.7	PM	134.1
VL	94.3	Ss	102.0	LD	107.0	VL	96.1	St	100.0	PPGb	132.5
RC	94.3	VL	100.4	GP	105.4	Sm	93.0	TFL	91.2	GP	126.4
TFL	88.0	GM	100.2	RC	103.3	Ss	85.4	VL	90.1	LD	115.7
Ss	82.4	St	100.0	Ss	102.1	TFL	82.3	Ss	87.7	T	114.6
PPGb	80.2	PPGb	99.1	PM	100.8	T	81.2	PPGb	87.1	GM	111.9
T	79.0	GP	98.8	T	100.4	PPGb	80.0	T	82.2	St	100.0
RF	72.2	PM	97.3	St	100.0	GM	71.6	RF	76.9	VL	95.2
GM	70.4	LD	93.6	GM	98.8	GP	68.2	GP	74.6	Ss	63.8
GP	68.8	TFL	92.0	CLaTB	97.5	RF	62.7	GM	70.9	CLaTB	56.1
LD	55.8	Sm	89.6	CLoTB	96.3	LD	52.5	LD	56.5	CLoTB	52.2
PM	34.0	RF	86.1	VL	92.6	PM	33.0	PM	33.0	RC	47.4

Table 7. Individual muscle (Mu) values (V) of various texture variables relative to those of the St muscle after 14 days of aging (= 100).

Variable											
hardness		cohesiveness		springiness		gumminess		chewiness		adhesiveness	
Mu	V	Mu	V	Mu	V	Mu	V	Mu	V	Mu	V
CLaTB	132.4	CLaTB	110.0	PPGb	108.8	CLaTB	144.4	CLaTB	124.8	RF	206.9
CLoTB	119.0	CLoTB	104.4	PM	107.9	CLoTB	123.6	CLoTB	110.5	TFL	189.5
St	100.0	RC	104.4	T	107.5	St	100.0	St	100.0	Sm	158.3
Sm	96.8	St	100.0	TFL	106.7	RC	94.1	RC	92.9	GP	128.6
RC	92.4	TFL	94.4	GM	104.6	Sm	86.1	TFL	88.7	GM	120.5
TFL	90.5	VL	94.2	LD	104.2	TFL	84.0	Sm	88.1	VL	118.3
VL	81.8	Ss	93.9	Sm	100.8	VL	75.7	T	78.5	LD	110.6
T	79.9	PPGb	93.5	St	100.0	PPGb	74.4	PPGb	77.8	T	108.5
PPGb	79.5	T	92.1	VL	100.0	T	72.4	VL	75.1	Ss	104.7
Ss	76.8	GP	91.6	RC	99.6	Ss	70.6	Ss	65.3	PPGb	101.4
RF	68.0	PM	90.7	RF	98.7	GP	60.5	GP	59.4	St	100.0
GP	65.2	Sm	87.9	GP	97.1	RF	57.3	RF	56.4	PM	98.6
GM	58.8	GM	87.6	Ss	92.5	GM	52.3	GM	53.1	RC	75.4
LD	49.4	RF	84.4	CLoTB	90.0	LD	39.8	LD	41.5	CLoTB	68.3
PM	35.6	LD	82.3	CLaTB	88.3	PM	31.8	PM	33.3	CLaTB	50.8

The marked individuality of muscle is also demonstrated by the high incidence of the component 'muscle' on total variance, namely within hardness, gumminess and chewiness: for the first two variables, the incidence of the component 'muscle' is higher than that of the 'error' (Table 4). This peculiarity of the muscle should have its own relevance in any programme of the genetic improvement of meat and is strictly related to its main function and therefore to its biochemical activity (Ranvier, 1874; Barany et al., 1965; Barany, 1967; Dreyfus, 1967; Goldberg, 1967; Burleigh and Schimke, 1968 and 1969; Short, 1969; Bass et al., 1969; Parsons et al., 1969; Mommaerts, 1970; Barnard et al., 1971; Sarkar et al., 1971; Ansay, 1974a, b, c; Matassino et al., 1974, 1975a, b, c, d).

In relation to the invariance of the rank the results were the following: (i) for hardness, the PM muscle always occupied the 1st rank, followed by the LD, GP and GM, the TFL usually took the 9th rank, the St the 12th, the Sm the 13th and the CLaTB always the 15th rank; (ii) within the cohesiveness, the RF always occupied the 1st rank, followed by the Sm and the CLaTB; the CLaTB always occupied the 15th rank; (iii) within the chewiness, the rank scale is the same as for the hardness (Tables 6 and 7). The aging period had no effect on the rank. After both 9 and 14 days of aging, the PM muscle produced better meat (the least hard, of lowest cohesiveness, the least gummy, the least springy and requiring less energy of chewing); follow the LD, the GP, the GM and the RF; the CLaTB and CLoTB produce meat which is the least hard, of more cohesiveness, the least springy and gummy and requiring the most energy of chewing; the PPGB generally had intermediate values (Table 8). Within muscles, the extension of aging time from 9 to 14 days tended to improve the meat characteristics (meat tends to become less hard, with a lower cohesiveness, less springy, less gummy and requiring less energy of chewing). The difference between the muscles, occupying the extreme positions in the rank, varied within each variable and, within this, according to aging time. These results are in agreement with those obtained with cooked samples of LD by Martin et al. (1971) who found that meat tenderness improved rapidly until the 6th aging day and much more slowly until the 13th day. The same results were observed by Webb et al. (1964, 1967). Further, Hoagland et al. (1917), Deatherage and Harsham (1947) and Doty and Pierce (1961) reported that aging effects do not increase after 2 weeks, even though Harrison et al. (1949) reported that tenderness increases up to the 4th week, while Larmond et al. (1969) found that aging effects end at the 10th day. In addition, Martin et al. (1971) observed that the LD tenderness of young animals tends to improve with the aging period independently from the fattening grade of the carcass and its sex. Holding constant the carcass weight after cooling, the separable fat

Tabel 8. Individual muscle (Mu) values (V) of various texture variables after 9 days (Mu_1) or 14 days (Mu_2) aging, relative to those of the St muscle after 9 days of aging (= 100).

Variable											
hardness		cohesiveness		springiness		gumminess		chewiness		adhesiveness	
Mu	V	Mu	V	Mu	V	Mu	V	Mu	V	Mu	V
$CLaTB_1$	144.6	$CLaTB_2$	114.6	RF_1	118.2	$CLaTB_1$	161.3	$CLaTB_1$	158.5	RF_1	302.1
$CLaTB_2$	133.7	$CLaTB_1$	109.9	TFL_1	109.5	$CLaTB_2$	154.9	$CLaTB_2$	134.2	RF_2	228.2
$CLoTB_1$	120.3	RC_1	109.3	Sm_1	108.7	$CLoTB_2$	132.9	$CLoTB_1$	124.9	TFL_2	209.1
$CLoTB_2$	120.2	$CLoTB_2$	108.8	$PPGb_1$	108.3	$CLoTB_1$	126.1	$CLoTB_2$	118.8	TFL_1	207.7
Sm_1	101.5	RC_2	108.8	$PPGb_2$	107.4	St_2	107.3	RC_1	108.6	Sm_1	187.0
St_2	101.0	St_2	104.2	LD_1	107.0	RC_1	103.8	St_2	107.5	Sm_2	174.7
St_1	100.0	$CLoTB_1$	103.6	PM_2	106.6	RC_2	101.0	Sm_1	101.7	GP_2	141.9
Sm_2	97.7	T_1	102.2	T_2	106.2	St_1	100.0	St_1	100.0	PM_1	134.1
VL_1	94.3	Ss_1	102.0	TFL_2	105.4	VL_1	96.1	RC_2	99.9	GM_2	132.9
RC_1	94.3	VL_1	100.4	GP_1	105.4	Sm_1	93.0	TFL_2	95.3	$PPGb_1$	132.5
RC_2	93.3	GM_1	100.2	RC_1	103.3	Sm_2	92.3	Sm_2	94.8	VL_2	130.6
TFL_2	91.4	St_1	100.0	GM_2	103.3	TFL_2	90.1	TFL_1	91.2	GP_1	126.4
TFL_1	88.0	$PPGb_1$	99.1	LD_2	102.9	Ss_1	85.4	VL_1	90.1	LD_2	122.0
VL_2	82.6	GP_1	98.9	Ss_1	102.1	TFL_1	82.3	Ss_1	87.7	T_2	119.7
Ss_1	82.4	TFL_2	98.4	PM_1	100.8	VL_2	81.2	$PPGb_1$	87.1	LD_1	115.7
T_2	80.7	VL_2	98.2	T_1	100.4	T_1	81.2	T_2	84.5	Ss_2	115.5
$PPGb_2$	80.3	Ss_2	97.8	St_1	100.0	$PPGb_1$	80.0	$PPGb_2$	83.6	T_1	114.6
$PPGb_1$	80.2	$PPGb_2$	97.4	Sm_2	99.6	$PPGb_2$	79.8	T_1	82.2	$PPGb_2$	111.9
T_1	79.0	PM_1	97.3	GM_1	98.8	T_2	77.7	VL_2	80.7	GM_1	111.9
Ss_2	77.6	T_2	96.0	St_2	98.8	Ss_2	75.8	RF_1	76.9	St_2	110.3
RF_1	72.2	GP_2	95.4	VL_2	98.8	GM_1	71.6	GP_1	74.6	PM_2	108.8
GM_1	70.4	PM_2	94.5	RC_2	98.3	GP_1	68.2	GM_1	70.9	St_1	100.0
GP_1	68.8	LD_1	93.6	RF_2	97.5	GP_2	64.9	Ss_2	70.3	VL_1	95.2
RF_2	68.6	TFL_1	92.0	$CLaTB_1$	97.5	RF_1	62.7	GP_2	63.9	RC_2	83.1
GP_2	65.9	Sm_2	91.6	$CLoTB_1$	96.3	RF_2	61.4	RF_2	60.7	$CLoTB_2$	75.4
GM_2	59.4	GM_2	91.2	GP_2	95.9	GM_2	56.1	GM_2	57.1	Ss_1	63.8
LD_1	55.8	Sm_1	89.6	VL_1	92.6	LD_1	52.5	LD_1	56.5	$CLaTB_2$	56.1
LD_2	49.9	RF_2	88.0	Ss_2	91.3	LD_2	42.7	LD_2	44.7	$CLaTB_1$	56.1
PM_2	35.9	RF_1	86.1	$CLoTB_2$	88.8	PM_2	34.1	PM_2	35.8	$CLoTB_1$	52.2
PM_1	34.0	LD_2	85.8	$CLaTB_2$	87.2	PM_1	33.0	PM_1	33.0	RC_1	47.4

and the percentage of chemical fat in the muscle did not improve the analysis of variance results (Matassino et al., 1974, 1975a).

Independently of the aging time, (i) the PM muscle is about 4 times more tender than CLaTB (2.15 and 8.55 kg respectively), (ii) the RF cohesiveness is about 75 per cent that of CLaTB, (iii) the PM gumminess if 4-5 times smaller than CLaTB, (iv) the CLaTB energy of chewing is 5 times higher than PM (Table 8). The effect of muscle, independently of breed, in a detailed analysis of the results showed that: (i) after 9 days aging out of 105 possible comparisons among muscles, 59 resulted in significant differences within hardness, 13 within cohesiveness, 54 within gumminess, 39 within chewiness and 30 within adhesiveness; (ii) after 14 days aging, the above values become 60, 23, 58, 45 and 24 respectively; (iii) considering both the aging periods, out of 435 possible comparisons, the significant differences are 108 within hardness, 22 within cohesiveness, 98 within gumminess, 70 within chewiness and 40 within adhesiveness; (iv) within muscle, within breed, the differences between 9 and 14 days of aging are not significant.

Concluding, this study points out the practival usefulness of the texturometric method to show the importance of some factors (breed, muscle, carcass aging) affecting carcass organoleptic characteristics and confirms the marked histochemical individuality of muscle and, at the same time, it suggests the usefulness of further studies to understand the complex problems of carcass evaluation in relation to marketing and the programming of genetic improvements plans.

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DISCUSSION ON SESSION 5 ON "ASSESSMENT OF MEAT CHARACTERISTICS, INCLUDING SAMPLING"

Discussion leader: Lis Buchter.

The discussion leader, introducing the subject, suggested that meat quality is a neglected field of study, and we should aim to get improved uniformity of methods, which are easily applicable.

Questions on specific papers

The following points were raised after B o c c a r d's paper.

Tinbergen. In U.S.A. last year, some workers were suggesting toughness could be divided into the effects of actin-myosin and cross-linking of collagen. Collagenases were used, and residual myofibrillar toughness then measured.

Boccard. By using various muscles we have found shear force and collagen content to be closely related in young bulls although there is much variation in shear force at the same collagen content. Apart from the amount and the solubility of the collagen its conformation (structure) is of importance.

Riordan. Why was a tough muscle chosen for study? Cooking of such muscles will make toughness less important.

Boccard. Toughness varies with age or weight of animal, but the variation with age is much greater in the tougher muscles.

After T i n b e r g e n's paper *Buchter* asked whether the important factors colour stability and reduction potential were mainly dependent on the individual animal or on technological factors during the handling of the carcass and meat.

Tinbergen. Both are involved. A high microbial count reduces shelf life. Impermeable film is important, to keep a low oxygen pressure. There are enzyme differences between muscles and between animals.

After his paper, *Hamm* affirmed that the surface of the muscle must be freshly cut when using the method he had described.

Tinbergen commented that although the centrifugation method is more accurate than other methods it does not give an absolute value. It had been observed, from the fat line on the tube, that some water is reabsorbed into the meat after centrifugation, which is a disadvantage of the method.

After J o s e p h's paper, *Kallweit* asked whether the carcasses were of the same grade and degree of fatness when the sexes were compared. *Joseph* replied that the bulls were leaner and he would have preferred to have controlled chilling, as the chilling may cause differences in carcasses differing in fatness.

General Discussion

With the aim of making the discussion time as balanced and efficient as possible the *discussion leader* had asked the contributors to the session to co-operate in the following.

The experts were divided into groups of two and each group was then asked to suggest simple procedures for the determination of one of the following meat quality characteristics - shear force (Boccard & Joseph), meat colour (Tinbergen & Cosentino), WHC (Hamm), and taste panel evaluation (Harries & Zeuthen) in a hypothetical beef production experiment. The hypothetical experiment was as follows. Determine and rank the meat quality producing ability of 8 bulls of 2 breeds (4 of each). Each bull is represented by 12 sons, 6 of which are slaughtered at 300 kg and 6 at 500 kg live weight. All the animals are raised at an experimental station and slaughtered within a 6 month period. The carcasses are to be split into commercial joints and two muscles are available for meat quality determination.

A. Shear force. On behalf of *Joseph* and himself *Boccard* proposed attention should be given to standardizing the following points.

1. Handling and storage. The temperature in the centre of the round should not fall below 10°C within 18 hours of slaughter.

2. Time after slaughter (ageing). The carcass should be in a chill room at 2°C for at least 7 days.

3. The muscles used should be (a) the longissimus dorsi at the last thoracic and first lumbar vertebrae and (b) a second muscle. There is a wide choice - it should be easy to remove and should have straight fibres: e.g. the semitendinosus is preferable to the semimembranosus since the latter is difficult to separate from the adductor.

4. Number of cores. These should be taken in the middle of the muscle where the structure is homogeneous. It was suggested that a minimum of 5 cores, each allowing 2 shearings with at least 2 cm spacing, should be taken. The cross section of the cores should be 1 cm square. Shearforce results should be expressed in Newtons per unit area.

5. Instrument. Any suitable instrument may be used if it cuts across the axis of the fibres.

6. Preparation. Heating to 60°C in the centre of the muscle is proposed.

7. Additional measurements. Besides shear force the collagen content should be determined by hydroxyprolin determination and if possible the polymerisation of it by a solubility test by cooking of the minced meat in water.

These proposals were discussed.

Buchter: Thought the proposed ageing time was too short.

Joseph: In our experiment, 7 days was long enough for heifers. Young bulls reached the same level of tenderness as steers after 14 days. The required period may differ between animals of different types.

Buchter: The semimembranosus muscle is very variable and results obtained on this muscle are often unsatisfactory.

Kallweit: What is the aim of the experiment? Ageing may not be important in comparisons.

Buchter: The aim is to rank the bulls in this hypothetical experiment. Our choice of the period of ageing is based on the fact that after a certain ageing time the shear force values become stable. The necessary time to obtain this is found by plotting shear force measurements against ageing time as shown in my paper.

Kreuzer: There is another advantage, that it is best to carry out texture and taste panel studies at the same time.

Cuthbertson: Is it desirable to adopt methods which differ from practice? E.g. in the U.K. the period of ageing is 5 days at most. The same holds for the problem of dark cutting.

Buchter: Achieving stability is important in the context of experiments. Dark cutting is a problem of transport and should be examined in other studies.

Joseph: Commercial conditions are difficult to define. The research procedures we are defining may not be close to practice but will give repeatability.

Harries: I agree the experimental procedure need not be related to practice.

B. Colour determination. *Tinbergen* and *Cosentino* listed the important factors as: choice of muscle and the piece to be measured (shape, direction of cut); the use of the reflectance spectrometer is to be preferred, with a careful selection of filters; the measurement of pH because of its correlation with colour (the exclusion of meat with high values is desirable); choice of an exact time post-mortem for the measurement.

Discussion on these points followed. On storage time, a period of 24 to 48 hours was proposed.

Buchter suggested measurements of vacuum-packed meat.

Tinbergen: Optimum time of 'blooming' must be taken into account.

Joseph: Hood puts meat under a "Saran" wrap and holds it for 1 hour at 2^oC to allow the colour to develop.

Tinbergen: The film needs to be oxygen permeable.

Boccard: Amount of pigments must be considered, and they change with age and vary in different muscles. More than one muscle is needed for the measurement.

Dumont: The colour of the fresh meat, as it is purchased, must be measured, but the colour of cooked meat is also important.

Tinbergen: I disagree. This will be a simple, brown, denatured, material in the cooked meat.

Buchter: There is a high correlation between the pigment in raw and cooked meat.

Dumont: Stability of the colour varies.

Buchter: Meat can fade under the spectrophotometer, and the technique must therefore be standardized.

C. Water-holding capacity. *Hamm* pointed out that this assessment is easier than that of colour. The method used would depend on the type of experiments. The filter-paper press method is well established. Three measurements (each on 300 mg) are needed to obtain a good average. The capillary method may be much simpler if the right commercial design is available. The time chosen to make the measurement would be 1-2 hours post-mortem in studies of watery beef, but 24 hours post-mortem in normal beef.

Buchter: Pointed to the fact that the physio-chemical determinations in beef experiments besides colour and WHC should also always include final-pH and % fat.

Kallweit: One to two hours post-mortem will be a time of change in rigor mortis

Buchter: A later time could be chosen to avoid this.

Boccard: What is the correlation between the loss of water during cooking and water-holding capacity?

I. Schön: There is not a good correlation, but level of fatness has an effect.

Kallweit: It is best to measure pH over a period of hours and follow its decline.

Buchter: It is preferable to have methods which can be applied to the sample in the laboratory under controlled conditions.

D. Taste-panel tests. *Harries* and *Zeuthen* jointly prepared proposals presented by *Harries*, as follows:

1. There should be a minimum of 8 tasters, trained, and chosen for their ability to discriminate and for their consistency. Four - eight samples per session could be tasted, and treatments would be randomised within samples on each occasion.

2. The numerical scale would be used. This would be, as used at MRI, +5, very tender, to -5 very tough in a total of 6 steps; juiciness from +5, very

juicy to -5, very dry (not related to likes or dislikes); flavour, from +5 strong beef flavour, to zero for no flavour and negative values for foreign flavours, with an adjective used to discribe them.

3. There would also be a c o l o u r s c a l e.

4. C o o k i n g m e t h o d. Two muscles were proposed. The l o n g i s s i m u s d o r s i would be frozen and cut by band saw to a standard size, cooked on a griddle plate at 170°C to a centre temperature of 70°C. The s e m i t e n d i n o s u s would be roasted at 150°C until it reached a temperature of 68°C at the center.

Buchter: This is an unhappy compromise. One muscle should be "rare".

Hardwick: How are results interpreted if a bull is high in one character but low in another? Is a scale of general acceptability suitable?

Harries: It is necessary to separate the characteristics but in addition a hedonic scale is used, from 'like extremely' to 'dislike extremely', taking account of all factors and weighting them as the taster prefers. But there are only 8 people on a panel, and hundreds would be needed to carry out consumer tests.

Zeuthen: Interpretation depends on what is required, and this is a problem which is not specific to this type of measurement.

Harries: The consumer has to be asked.

Buchter: What temperatures should be used? Is 55°C suitable for 'rare' cooking?

Joseph: Is it proposed that the samples will be frozen?

Buchter: Yes.

Harries: The design proposed was specifically for the hypothetical experiment suggested, and other experiments may not need the same approach.

Williams: It may be necessary to have 20 trained people to assemble a panel of 8.

Buchter: We have managed with 9 people, assembled 30 times over 10 weeks with usually only one omitted from the panel.

Zeuthen: Our method of working with people from outside the laboratory is also satisfactory.

After the session, *L. Schön, Hamm* and *Kallweit* pointed to the fact that too little attention had been devoted to the quality of meat in relation to its technological use as for example in sausages etc.

Part 6

RELATIONSHIP BETWEEN MARKET VALUES, DISSECTION DATA, CARCASS CLASSIFICATION, AND MEAT CHARACTERISTICS

EEC Seminar on Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments, Zeist, 1975.

RELATIONSHIPS BETWEEN MARKET VALUE, DISSECTION DATA, CARCASE CLASSIFICATION AND MEAT CHARACTERISTICS

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Abstract

With the present marketing system in Great Britain, differences in the valuation of carcases due to quality variations are difficult to detect against the general background of variation of price, variations in specific demand, difficulties of quality assessment and trading pressures.

Furthermore, market valuations of different qualities, even when established through large samples of data which allow other effects to be averaged out, do not always coincide with theoretical valuations based on cutting tests and desk calculations of realisation values. This is because traditional views and aesthetic preferences still affect retailers appraisal of carcases in the market.

All this results in the beef producer knowing he must generally avoid excessive fatness and "under finished" animals that will kill out poorly, but beyond this he receives no clear direction from the market on the type that will be most beneficial for him to produce.

It is difficult for him to evaluate the benefits of any production change which is directed at carcase improvement, and the industry in total has no clear incentive to invest in livestock improvement as far as carcase and meat quality is concerned.

The role of carcase classification schemes in improving the transparency of the market and in providing clear signals to producers is described, and the roles of fatness and conformation discussed. The development of the concept of "target beef" in Britain is explained; this is an attempt to clarify improvement objectives, at least as far as mass market demand is concerned, and to secure a clear incentive for the improved type.

Introduction

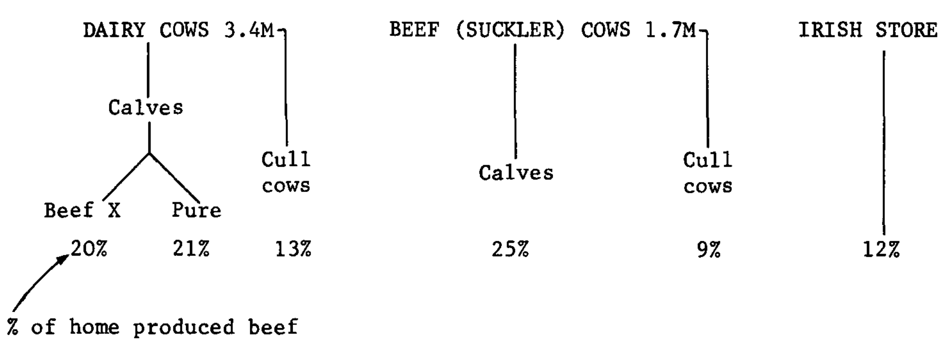
This paper lies outside the main theme of this Seminar, which is concerned with methods of assessing carcase and meat characteristics in beef production experiments. Those who drew up the programme obviously had in mind that we should stand back at the end of this Seminar and consider again why we take note of carcase and meat characteristics in our beef experimentation, which differences are of commercial and economic significance both in the short and longer term, what are their relative importance and how are the results to be interpreted? And then to draw conclusions about where co-operative research effort should be directed.

There are, of course, major differences between beef production practices in Great Britain and continental Europe, and between the types of beef traditionally demanded (although obviously the demand and preference differences arise to a large extent from traditional differences in the nature of the supply). These differences must affect the direction of our production research and how we evaluate the results. Some of the major parameters in Britain will be pointed out; others can highlight important differences between countries during the discussion.

Beef production in Great Britain

The beef sold in British retail shops is predominantly steer and heifer beef - with about two steers to every heifer. In total, steers contribute about 50% of total carcase weight produced, heifers 19%, young bulls about 1% and mature males and females about 30%. A high proportion of the latter is diverted to manufacturing uses.

Table 1: Production of beef in Great Britain from dairy cows, beef cows and imported store cattle



Cow beef production forms the smallest proportion of the total production and of the retail market in any EEC country (except perhaps Ireland), because a high proportion of their progeny are reared to finished cattle weights, and most of this cow beef is diverted into manufacture. Secondly, the production of young bulls for beef is not yet well established, despite the clear economic advantages, for the following reasons:

(a) Legislative factors - causing positive discouragement or, at least, creating additional difficulties for the more adventurous producers,

(b) Trade concern about the incidence of dark-cutting beef,

(c) Limited trade preference for the low levels of fatness achieved by young bulls,

(d) General resistance to change.

In Britain, there is one beef cow in the breeding herd for every two dairy cows (see Table 1). Crossing of dairy cows with bulls of beef breeds is widely practiced and a high proportion of the purebred and crossbred calves from these dairy cows are reared to beef. But because of the need to generate replacements, a significant part of beef production is from steers of the dairy breeds, predominantly Friesian.

Table 2 shows our estimates of how beef production from young cattle is made up according to breed type.

<u>Table 2: Percentage of beef production in Great Britain according to breed type</u>

<table>
<tr><th></th><th></th><th colspan="4">Breed of cow</th></tr>
<tr><th></th><th></th><th>Friesian</th><th>Ayrshire</th><th>Beef type</th><th>Other</th></tr>
<tr><td rowspan="3">Breed of bull</td><td>Friesian</td><td>30</td><td>*</td><td>*</td><td rowspan="3">4</td></tr>
<tr><td>Ayrshire</td><td>*</td><td>2</td><td>*</td></tr>
<tr><td>Beef type</td><td>25
of which
13 Hereford X
4 Angus X
6 Simmental/ Charolais X
2 Other X</td><td>2</td><td>34
of which
20 Hereford X
5 Angus X
9 Other X</td></tr>
</table>

* Small percentage

The typical beef production system brings cattle to slaughter at 18 months of age, but the average age at slaughter is probably rather more than 18 months, with the small number of cattle killed at about one year of age being matched by a rather higher proportion killed at two years of age and more. The feeding of grass through grazing or through conservation is the basis of most production systems. The average carcase weight of steers is about 580 lb (ex KKCF) and of heifers 490 lb, with the average carcase fatness about 25% - much higher than in most of continental Europe.

There, beef is sold to the consumer trimmed almost entirely of fat. This is not the case in Britain where the consumer is prepared to accept quite a high amount of fat in the beef purchased - the average over all the carcase beef sold across the retail counter (mostly without bone) is probably about 18% fat. This is traditional and is fostered by many meat traders who encourage housewives in the belief that this level of fatness is essential to ensure good eating qualities despite much scientific research to the contrary. Nevertheless the consumers aversion from fat (brought about by price increases and the associated greater consciousness of waste, preference for slimming foods, fear of saturated fats etc,) is undoubtedly increasing even in Britain, and bringing with it a greater trade preference for leaner cattle.

<u>Quality differentiation in marketing</u>

In Great Britain, the methods used by wholesale buyers in purchasing beef carcases (whether on live or deadweight basis) are not very sophisticated. They will penalize live animals which they believe will give a low killing-out percentage and their carcases which may be considered "under-finished", and they will penalize carcases which are excessively fat by their standards. These two factors together may cover perhaps 10% of beef cattle produced. Among the other 90% there is differentiation in price but it is not very easily discerned by the producer.

This is not to say that when the retailer comes to cut and prepare his carcases they do not vary considerably in realisation value to him. However there is a surprising lack of awareness of these variations or concern about them among retailers. This is partly because a high proportion of the meat trade in Great Britain is in the hands of independent butchers who cut up a small number of carcases each week, do not keep any records, are not able to make precise comparisons between the qualities of carcases from particular sources and who are heavily influenced by their traditional beliefs about what leads to superior yields and superior meat qualities.

Moreover, the larger retail firms who have much more accurate costings and who are aware of the variations, are nevertheless buying in a competitive situation from many suppliers some of whom are quite small and who find it difficult to select carcases to precise specifications. The concern of these firms is very much to buy the right average carcase quality at the right price. They recognise some benefits in decreasing the variability of what they buy but, in practice, find it difficult to exercise tight control.

We asked seven multiple meat traders to cut up a sample of their own beef carcases using their own particular methods (see Figure 1). This demonstrated the wide variation they were buying, and the relationship between the amount of fat trim by their standards (the primary determination of realisation value) and our particular measures of carcase fatness.

But the wholesaler is unable or unwilling to reflect these differences in ultimate realisation value back to the producer in a clear way. There are four reasons for this.

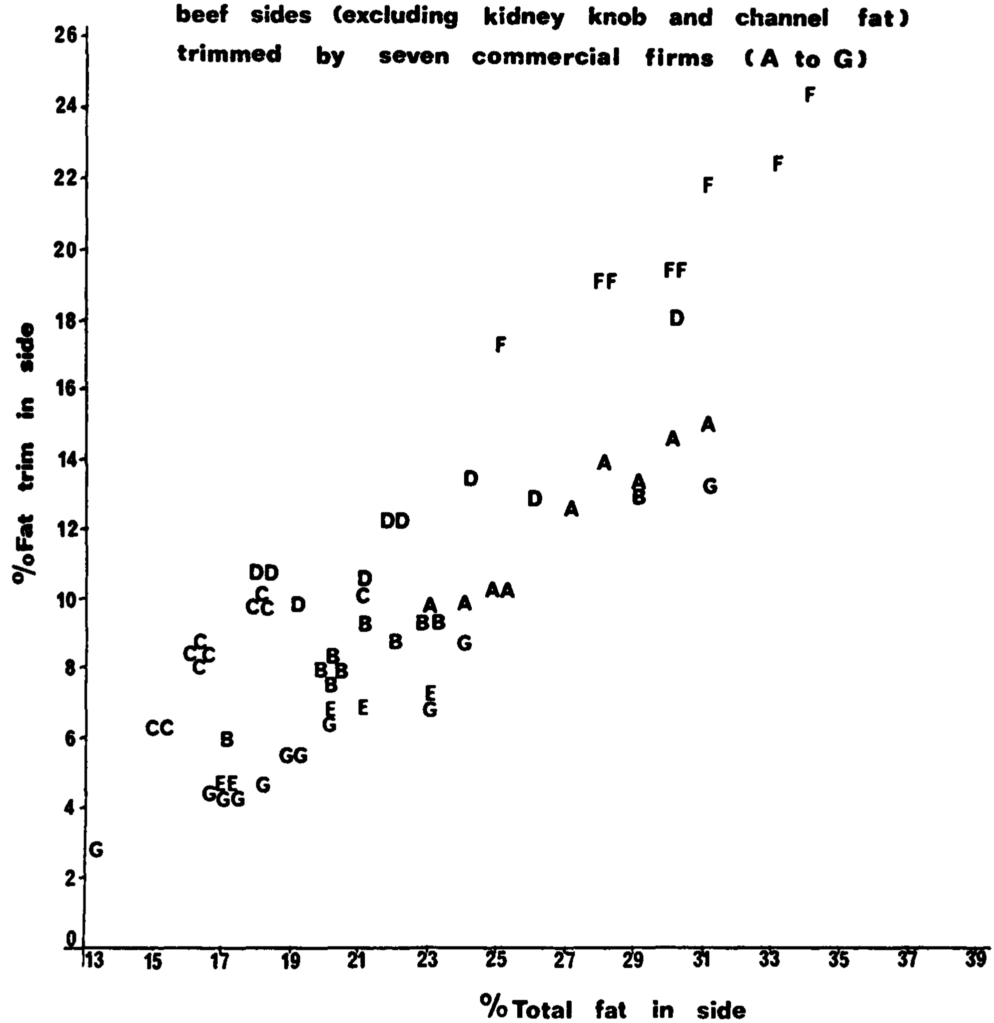
(a) Demand from individual retailers does vary a good deal according to different areas and market outlets although in many cases it is not very specific; the skill of the wholesaler is to match his variable supply with the variable demands of his customers.

(b) There are considerable difficulties in quality assessment in the commercial situation.

(c) Perhaps most important of all, the trading situation makes it difficult for the wholesaler to create and maintain wide differentials between animals of above and below average quality. In the wholesaling business, obtaining the necessary turnover is of overriding importance, and considerable attention is paid to maintaining the flow of supplies from particular producers who generally produce cattle of acceptable quality. To penalize the worst of these cattle, may lose the wholesaler the whole supply. There is real difficulty for any wholesaler who seeks to differentiate price according to quality in competing with other traders who operate buying systems which average across qualities. In addition, there are other problems - for example, the need to operate with full lorry loads - which distort prices.

Fig 1

Percentage fat trim against percentage total fat for 64 beef sides (excluding kidney knob and channel fat) trimmed by seven commercial firms (A to G)



(d) Price is very responsive to local variations in the balance of supply with demand, and such variations overshadow and obscure variations due to quality.

The result of all of this is that the beef producer in Britain knows he must generally avoid excessive fatness and knows that "under-finished" carcases or "under-finished" animals that kill out poorly will be penalized, but beyond this he has no clear direction from the market of the type of animal that will be most beneficial for him to produce.

The implication of this for production experiments is that they could be evaluated on the basis of the efficiency with which feed is turned into carcase weight, providing that slaughter weights are such as to avoid excessively fat carcases and that nutritional levels and slaughter weights are high enough to avoid the under-finished animal. This however is very much the short term view.

Consumers primarily want lean meat with a minimum of adhering fat. Apart from this, other aspects of carcase quality do affect the value of the carcase to the retailer. So for experiments of long term significance, assessment must relate to the ability of the animals to convert their feed into lean meat of acceptable quality, and in a carcase form most advantageous to efficient utilization by the butcher.

Various methods are available for estimating the fatness of the live animal and of the carcase, but few methods are sufficiently accurate for estimating the lean content directly or for estimating muscle to bone ratio.

In production experiments of long term significance, therefore, a significant proportion of the animals involved must be cut up to provide a measure of lean content. As we have heard, two approaches are available - the scientific approach, by which carcases are dissected to give an accurate lean meat percentage, or semi-standardized commercial approach which concentrates on deboning the meat and trimming it to as consistent a degree of fatness as is possible. The former method costs about 10 times as much as the latter and there is no doubt that for most experiments, the second approach is quite adequate. Usually the precision of an experiment or breeding programme can be improved much more by increasing the number of animals involved than by increasing the accuracy of the measurements taken on individual animals.

As emphasized by the EAAP Working Party, (De Boer, Dumont, Pomeroy and Weniger, 1974), the so-called "morphological" characteristics such as fat thickness, flesh thickness etc are undoubtedly related to some degree with percentage composition. In addition, De Boer and de Rooy (1971) have shown significant relationships between these morphological characteristics, particularly fleshiness, and wholesale valuations of young cows. But the extent to which these traits relate to the value of the carcase to the retailer in respects other than meat yield is not yet clear. In other words, do shape and tissue distribution affect the true valuation of carcases, by the retailer of similar percentage composition?

Better quality differentiation through carcase classification

There is of course the possibility - indeed the hope - that market organisation will change and the industry will find ways of explicitly attaching higher values to better than average carcases and of discounting more clearly those poorer than average. This will only be achieved when there is a nationally accepted carcase classification scheme, applied in the standard manner to as high a proportion of beef carcases as possible, with the producer, wholesaler and retailer properly informed and the industry helped and encouraged to use this in market valuation.

The method of carcase classification which we have developed is now applied to 45% of all cattle slaughtered in Great Britain and involves a visual judgement of fat class and of conformation class in addition to weight, sex and (in some cases) age determined by dentition (Cuthbertson and Harrington, 1973, Harrington, 1973 and Meat and Livestock Commission 1975 a.). In developing the scheme, considerable attention has been paid to the practical problems of application under commercial conditions, and the need for such a scheme to be seen to be relevant to the traders who will use it.

Some important decisions that have been made are:

(a) The classification must be made on hot sides of beef - so quartering to show eye muscle area is not possible,

(b) No technique available for measuring lean meat depth are sufficiently practical or accurate to allow their use in commercial classification,

(c) Although fat measurement at one or two sites by probing might be feasible, it is not sufficiently more accurate than eye judgement to justify its incorporation,

(d) Intermuscular fat cannot be estimated on the side of beef - so the fat classification is based on external fat development in full knowledge of breed differences in fat distribution,

(e) Conformation is defined according to the EAAP definition (de Boer et al, 1974); this has been adopted rather than "fleshiness" or "muscularity" because of the difficulties of assessing "muscle and intermuscular fat" or "muscle" development on British cattle at relatively high levels of fatness, and because fatness is assessed separately anyway,

(f) In order to describe variations among British beef carcases with sufficient discrimination for commercial purposes, 5 basic classes are needed for conformation, and 6 for fatness although in both cases some further discrimination for certain purposes is required at the extremes of the scale.

Photographic reference scales are used to show the variation in shape and fatness covered by the scheme. Table 3 shows the percentage of classified carcases achieving each class combination from October 1974 to March 1975, based on a one third sample of 700,000 carcases classified during this period.

<u>Table 3: Percentage of classified beef carcases achieving each class combination between October 1974 and March 1975</u>

	1 (Leanest)	2	3 L	3 H	4	5	Z (Fattest)
5 (Best Shape)	-	0.2	1.2	2.3	1.9	0.3	-
4	<0.1	1.8	6.7	7.4	3.2	0.4	<0.1
3	0.2	11.2	21.1	12.3	2.8	0.3	<0.1
2	0.6	9.5	8.0	2.8	0.4	<0.1	-
1	1.0	2.5	0.9	0.2	<0.1	-	-
Z (Worst Shape)	0.3	0.1	<0.1	<0.1	-	-	-

The correlation between fat class and conformation class when defined in this way is clear, but nevertheless the full range of conformation is found in the commercially very important fat classes 2 and 3.

There is an objective definition behind the fat classification based on ranges of subcutaneous fat %, so that if carcases are correctly classified for fatness there is a big difference, on average, between the classes in carcase fat %s by dissection (hence in the carcase lean %), as Table 4 relating to 650 steer carcases shows.

Table 4: Average composition of beef carcases in each MLC fat class

	External fat class					
	1	2	3L	3H	4	5
Range of subcutaneous fat % in carcase	< 4.5	4.5-7.4	7.5-8.9	9.0-10.4	10.5-13.4	≥13.5
% lean	67.8	64.2	61.0	58.8	55.5	51.8
% total fat ex KKCF	13.8	18.3	22.4	25.2	29.6	34.3
% bone	17.1	16.1	15.2	14.6	13.7	12.7
% waste	1.4	1.4	1.4	1.4	1.2	1.2
% KKCF	3.4	3.9	4.3	4.6	5.1	5.6
Lean/bone ratio	3.9	4.0	4.0	4.0	4.1	4.1
Subcutaneous fat/ intermuscular fat ratio	0.38	0.53	0.63	0.68	0.74	0.80

In practice two thirds of the carcases can be correctly allocated by eye judgement to their true fat class on this definition. Weight, coupled with fat classification, does explain up to 55% of the variation in the yield of saleable meat but a point of major concern is whether the inclusion of carcase conformation in the prediction increases the precision of the estimate. Clearly, the increase in precision cannot be very great, since no factor that can be assessed on the intact carcase is closely related to the meat to bone ratio.

Table 5 shows the lean content (% by dissection) of a large sample of beef carcases of mixed breed and weight. Among carcases in the important fat classes (2 and 3), there is some evidence that lean meat content is related to conformation, but the effect is not very large.

Table 5: Average percentage of lean meat among carcases of each class combination

Large sample of beef carcases

Conformation class	Fat class 1 (Leanest)	2	3	4	5 (Fattest)
5 (Very good)	(69.0)	64.7	61.5	55.4	52.0
4	69.7	64.7	60.7	55.7	54.0
3	68.8	63.9	60.2	57.0	(52.8)
2	69.0	64.7	59.5	55.6	(53.9)
1 (Poor)	68.4	63.4	59.5	-	(52.4)

(Brackets indicate less than 5 carcases)

If the sample is broken down into individual breeds and crosses (Table 6) however, it can be seen that:

(a) Within breeds and crosses there is little or no relationship between conformation and meat yield among carcases of similar fatness.

(b) Between breeds there are important shape related differences in meat yield, especially between dairy breeds and the muscular continental beef breeds.

This means that attempts to relate conformation to meat yield can produce varying answers according to the breed mix in the population sampled. (A similar situation has been hypothesized to explain contradictory results with pigs (Harrington, 1972)).

If the market expresses a preference for better conformation at low levels of fatness, therefore, this should have the effect of encouraging the adoption of breeds in commercial production which will bring with them a high yield of saleable meat and therefore economic advantage. However, it also means that it is probably a waste of time putting any great emphasis on conformation in experiments where animals of the same breeds are involved or in within breed selection programmes, except in so far as conformation is shown to be related to other aspects of the retailer's valuation.

The inclusion of conformation in commercial classification is justified for three other reasons.

Firstly there is no doubt that there is a relationship between conformation and the thickness of the lean meat (as opposed to its yield) among carcases of similar weight and fatness and that these differences are valued by the meat trade - subjectively at least.

Secondly, there has been a reluctance in Britain to accept carcases at lower levels of finish, despite the economic desirability of this, because generally these are associated with poor conformation in British breeds under British conditions; we have found that carcases of low levels of fatness are much more acceptable to the meat trade when they are all of good conformation even though they may not have a much higher yield of saleable meat.

Thirdly, in Britain, we have increasing variation in conformation due to the introduction of breeds of good conformation (and muscularity) from continental Europe, and of poor conformation (and meat yield) such as the Canadian Holstein.

Improvement targets

On a long term basis, there must be a need to move the average British beef carcase from 33 (on the above classification scheme) towards the 24, preferably with an increase in carcase weight, and with an improved food conversion (Meat and Livestock Commission, 1975 b.).

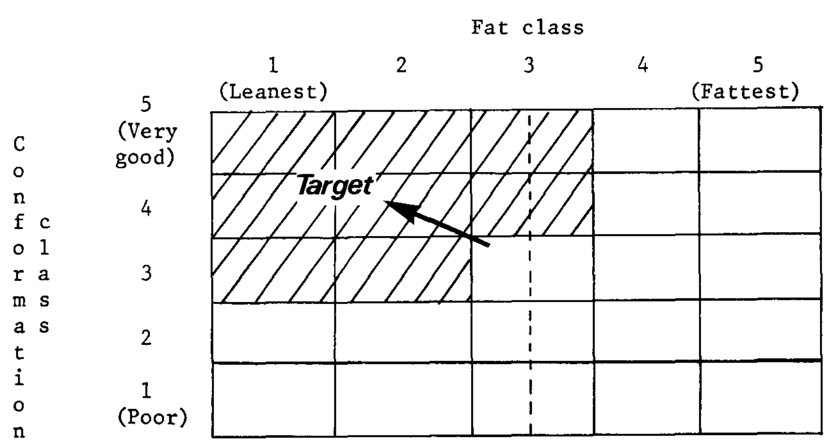
Table 6: Average percentage of lean meat among carcases of various class combinations within 11 breed types

	Fat class 2 Conformation 1	2	3	4	5	Fat class 3 Conformation 1	2	3	4	5
Friesian x Ayrshire (23)		61	62				58	58½		
Friesian (177)	64	64	63½	63		60	59	59½	59½	
Hereford x Friesian (78)	63½	64½	64½				61	60	60½	61½
Simmental x Friesian (45)		65½	64	64½			59½	60½		
Charolais x Friesian (6)			63½	64½	65½				61½	61½
South Devon x Friesian (6)		64								
Angus crosses (71)							60	58½		
Welsh Black crosses (71)			64½	64				61½	61½	
Mixed sample (25)		64½	64					61		
Limousin x Friesian (27)			67	66½						
Simmental x Ayrshire (20)		65	61½					59		

(The numbers of carcases of each breed are given in brackets - also only individual averages based on more than four carcases have been included.)

The scale of advantage in carcase terms that might be achieved by such a change can be assessed from Table 7. Not all these need be the subject of conscious selection - some would be achieved by correlated responses to attempts to change weight, fatness and conformation.

In an attempt to short-circuit trade reluctance to modify its buying practices and to link price positively with clear grades defined in classification terms, the concept of Target Beef is being introduced to clarify improvement objectives to producers and, at least as far as the demand of the mass market is concerned, to encourage the emergence of clear incentives for them to move towards the improved type. Target Beef is defined as the following classes in conjunction with a suitable minimum weight:



What is important is the proportion of carcases falling into the Target Group rather than the identification of an individual carcase as target beef as would be the case if this were a carcase grading scheme. Nationally we achieve about one third of carcases in this group, but 78% has been achieved in some Hereford progeny tests, 83% and 90% by different groups of Limousin x Friesians and 100% of our first test group of Blond d'Aquitane crosses.

Meat characteristics

There is growing awareness that the appearance and eating characteristics of the meat are affected as much by the treatment of the animal before slaughter as by the handling of the carcase after slaughter. In these circumstances it is difficult to see that great emphasis should be placed in experimental work on

Table 7: Comparison of current average beef carcase with an improved beef carcase

	The current average beef carcase	Direction of change	An 'improved' beef carcase
MLC Classification	33		24
Carcase weight (lb) (ex KKCF)	550	↑	600 + (say)
Fat cover Thickness over the eye muscle at the 10th rib	11 mm	↓	8 mm
External fat (% carcase weight)	9	↓	6
Total fat in side (% carcase weight)	24	↓	18
Lean to bone ratio	4.0	↑	4.5
Lean meat thickness Depth of eye muscle at 10th rib	65 mm	↑	85 mm
Percentage of total lean meat that lies in high priced cuts	49.0	↑	49.5
Saleable meat yield (%)	68.5	↑	72.5
Killing-out percentage	55	↑	56

eating characteristics. Obviously gross colour differences and gross flavour deterioration (possibly due to different types of feed) must be looked for, and it may be worthwhile in feeding trials and selection experiments to look for tenderness differences.

Much energy has been expended in seeking to detect differences in tenderness in different types of beef. Providing the beef is young (as the bulk of it will be under modern production systems) then the differences which have been detected between groups, even when statistically significant, have been small and cannot be considered important in relation to the wide range acceptable to the consumer and the wide range of variation found in commercial beef due mainly to age and handling variations. Processing characteristics are likely, of course, to develop greater importance in the future.

Cooperative research projects

This paper comes in the session entitled 'Consideration of possibilities of co-ordination and of requirements for future research'. Obviously there are many areas of research in carcase evaluation which will be pressed forward in individual countries seeking to improve methods of fat and lean meat estimation of live animals and carcases, working towards more effective carcase classification schemes within individual countries and, in due course, a common classification scheme for the EEC.

In my view, one of the most suitable areas for cooperative research concerns the comparison of breeds on various feeding regimes to various weights with, in particular, a close study of the variation in the meat to bone ratio and its relationship with conformation between breeds. As already mentioned, the relationship between morphological characteristics and retailer valuation among carcases of similar weight and composition should be explored cooperatively.

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RELATIONSHIPS BETWEEN MARKET VALUE AND MEAT CHARACTERISTICS

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Abstract

Two methods of valuing carcasses are considered. First it is argued that prices paid for carcasses from experiments are an unreliable guide to the relative potential market values of output from different treatments, especially when there are qualitative differences between the carcasses. An alternative to open market pricing is then proposed using carcass jointing. The Codex Alimentarius pistola less shank (I/7.2.8) is divided into seven standardised and boneless cuts. The rest of the carcass is also deboned and valued as one unit. The similarity of these cuts with boneless primal cuts in trade means that prices for valuing each cut could be derived from the target market. The sum of the resulting values could then indicate a market value for the carcass.

Tests of market homogeneity of cuts between treatments are proposed using models of the valuation of lean and fats in each cut. In essence these are conjunctive models postulating that the levels of <u>all</u> the major characteristics of a cut must lie within the boundary of acceptability, for the cut to be accorded full market value. Adjustment of market values for defects in the characteristics of a cut are also proposed.

Thus the proposed alternative to open market pricing is a synthesis of the valued elements of a carcass similar to a production function that combines data on input ingredients to yield an expected value of output.

Introduction

To evaluate any change in production technology certain questions have to be asked about the quality as well as the quantity of the output. If, for instance, a new technology or treatment does not affect the qualitative characteristics of output then the ratio of quantities between treatment and control gives a ratio of their market values. However, if there is a difference in the qualitative characteristics of outputs from treatment and control then the ratio of quantities may need to be adjusted to show their relative market values. The adjustment would essentially be the ratio between the potential prices of output from the treatment and control.

The admission of qualitative differences between various outputs raises problems that demand attention because:

1. The bigger changes in production technology are more likely to involve notable changes in the qualitative characteristics of output, for example, the switch from steer to bull beef.
2. Change in the characteristics of beef output is a warrented aim in itself and is needed to raise the demand for beef.
3. Knowledge of the relationships between beef characteristics and its value is even required to determine whether a treatment has left the potential price of output unchanged. For even to test this hypothesis it is necessary to state:
   (a) the characteristics to be assessed,
   (b) how the characteristics are to be assessed,
   (c) decision rules for judging whether data on the characteristics of beef from two treatments are likely to result in these two sorts of beef obtaining different market prices.

Deficiencies of open market pricing of qualitatively different outputs

The assumed aim is to discover how much money would be paid for a carcass from one treatment relative to a carcass from another treatment or control, in an open market economy, particularly a market in the European Economic Community. In the economists' perfect market the answer is simply: the highest prices offered for the carcasses in that market. However, valuation by selling the carcasses is likely to be misleading for the following reasons:

1) Imperfections in the beef market lead to errors in adjusting the market price for visible differences between carcasses. Pricing defects are likely to include under-estimation of some differences, bias, and large dispersions of prices about the average for a treatment.

2) Prices offered for carcasses would generally have to be based on assumptions about the palatability of the meat. These assumptions may well be false for beef produced by new technologies. Thus if the buyer assumes 'no difference' he may be wrong, but if he knows there is a difference, he cannot know the full implications of this difference for the value of the meat. In such a risky situation a buyer will offer a discounted, and lower, price than might be justified by the state of the final market(Keane and Riordan, 1973).

3) Current relative values of carcasses from different treatments may distort the selection of production technologies that will provide beef for consumption 5 years or more later.

Thus it would be advantageous to be able to make systematic allowance for the effects of likely changes in:

(a) Consumers' tastes in such matters as: all sorts of fatness, meat texture, colour; as well as developments in cookery, shopping habits and life-styles. Similar changes occur with the opening of new markets, such as the German market for Irish beef producers.

(b) The technology of beef distribution from farm to table, for example, the development of trade in primal cuts in place of carcasses.

(c) The changing availability of various types of beef.

(d) The organisation and operation of the marketing process in so far as it affects the retail pricing of beef and the relaying of price differentials throughout the market system. Carcass classification may bring such changes when it is introduced or when it is changed.

Thus the current value of carcasses in trade could be a very defective indicator of the relative market values of output from two treatments or technologies. One alternative is to synthesise market valuations of carcasses from a model of how the main elements of a carcass are valued.

The Synthesis of Market Valuation - An Alternative to Open Market Pricing

Let us then explore a beef valuation model. The first step will be to produce a fairly elaborate model, remembering that it should be possible to establish relationships between the various parts of the model that may simplify its application.

A common starting point is to view the carcass as a grouping of muscles, fats, bones and connective tissues. The key questions are then

1. What proportion of these tissues are eaten without radical manufacture?

2. What gustatory and monetary value can be put on those tissues that are eaten?

3. What value can be put on tissues going for manufacture or waste?

Considering the valuation of tissues that are eaten we may divide the muscle tissues into those that are acceptable after fast cooking, e.g. grilling or roasting, and the rest that have to be cooked slowly. Let it be accepted that this division largely rests on the differing characteristics of muscles and is to be seen in butchery cutting lines. The division between fast and slow cooking is also very marked in the scale of market valuation, with higher prices for steaks etc. reflecting their greater culinary convenience and expected palatability. The main parts of the carcass usually acceptable for fast cooking are then the filet, loin, rump, round and best ribs, that is, most of the meat in the Codex Alimentarius beef pistola (I/7.2.8) cut at the 5th rib from the neck and excluding muscles of the leg distal to M. semimembranosus, M. semitendinosus, and M. biceps femoris (Annexe)

Valuation of Pistola less Shank

Accepting this approximate boundary of meat likely to be acceptable for fast cooking allows attention to be given to:

1. The gustatory or palatability evaluation of meat from parts of the carcass suitable for fast cooking, let us say the pistola less shank.

2. Evaluation of carcass fats from the pistola less shank.

Valuation of Lean: The palatability of a steak or roast beef is mainly a function of its texture, juiciness and flavour. At least two unrelated scales are required to express these appraisals (Harries et al.,1972). A model of the valuation process thus has to combine several unrelated appraisals into a single market valuation. It seems unlikely that the scales will be compensatory and thus they cannot be added together. That is to say that a tough steak is of low value almost regardless of its flavour (Brayshaw 1967). A more successful type of model is likely to accept a steak if each of its characteristics attains a certain minimum level. Such a conjunctive model would require that the steak has at least a given level of tenderness and juiciness and good flavour if it is to be an acceptably enjoyable steak. Within groups of steaks that are acceptable on all these criteria choice may then be a function of visual criteria. No direct test of this hypothesis has been found but the results of some experimental work show that a conjunctive model is likely to be quite common in repeated everyday appraisal of items with non-compensatory attributes (Wright, 1975).

The valuation of one steak must then be generalised if it is to have market relevance. The generalisation would be towards an expectation of the likely value of a steak from a particular treatment or source of supply. Such an expectation could be expressed as the probability of a steak from the treatment being acceptable when eaten. The probability of acceptance being derived from entering the measurements of characteristics of a specific cut into a conjunctive appraisal model of the cut. Valuation of these steaks might then be a continuous function of their probability of acceptance. However, at low probabilities it makes more sense to cook the meat slowly. With high probabilities of acceptance a rare departure from acceptability may be disregarded especially if expectations of acceptability are supported by advertising (Cohen and Goldberg, 1970).

A conjunctive model for market valuation of beef does not seem to have been tested*. However, the model does admit several of the phenomena of market valuation. For example, the model allows for differences between the value of lean meat in fillet steak (M. psoas major) and topside (M. semimembranosus) as a filet steak is much more likely to be acceptable than one from the topside. Similarly the higher probability of getting an acceptable porter-house steak

*However the apparent predictive power of Bettman's shopping model based on cut-off points is encouraging.

(M. longissimus dorsi) from a USDA 'choice' carcass relative to 'good' and especially relative to USDA 'standard' is reflected in the grade price structure (Williamset al., 1959). The model also takes full cognisance of consumer concern about the variability of beef especially those cuts that are often cooked quickly as steaks etc. Consumers not only complain about the unreliable palatability of beef, their concern is even measurable. An observation study of Dublin housewives buying beef showed that buying a pre-packed round steak was twice as difficult as buying pre-packed bacon rashers of similar cost. Furthermore these shopping difficulties reflected the variability of eating characteristics in the round steaks being sold (Riordan and Connolly, 1975).

Important extensions of the conjunctive model would be the inclusion of tests for degree of colour, and colour stability, while quantitative adjustment might be made for potential drip loss and size of cut.

The implications of this lean meat valuation model on the assessment of beef from experimental treatments depend on the aims of these treatments. In this three experimental designs might be recognised as follows:

(i) Experiments designed to show causal connections between treatments and meat characteristics, with emphasis on detection of differences between treatments - topics covered by earlier papers in the seminar.

(ii) Screening tests of the output of treatments not intended to affect palatability. The aim here would be to pick out only those treatments notably affecting the probability of the meat being acceptable in the target market. A market valuation approach would be relevant with a sequential sampling design.

(iii) Intensive testing of meat from treatments likely to have a notable impact on the acceptability of the lean and thus its valuation in the target market.

Applying the proposed valuation model in cases (ii) and (iii) involves:

(1) Setting one or more rejection levels for each of the main characteristics of beef using standardised methods for measuring the characteristics.

(2) Obtaining data for all the relevant characteristics from each sample

(3) Attention to the distribution of the data relative to the rejection level, joint probabilities of rejection etc. rather than to average scores for each characteristic of meat from a treatment.

(4) Intensity of sampling rising with proximity to the rejection levels, thus in many cases greater attention would be paid to M. semimembranosus than M. longissimus dorsi.

A study that went some way in the direction suggested by this valuation model was reported by Juillerat and Kelly (1971). They obtained the preferences of American households using pairs of steaks cut from M. semimembranosus and found statistically significant relationships between the probability of preferences and

a) The Warner Bratzler value of a sample steak exceeding a fixed level and

b) USDA grade.

Fat Valuation: A conjunctive model may also be considered for beef fatness. A market might then be described by stating the levels of subcutaneous, inter-muscular and intra-muscular fat in a particular cut that would have a high probability of acceptance. Then beef that both satisfied this specification and was very likely to have acceptable lean would tend to command the highest retail price. In this case the price of fat would equal the price of lean. However, should the degree of subcutaneous or inter-muscular fat differ from that specified for the market, the valuation could well be a linear function of the degree of overfatness. A linear function is postulated on the ability of shoppers to guage the level of fat in retail beef and the scope for cutting off subcutaneous and some inter-muscular fat before retail sale. Any serious degree of overfatness that required trimming may have a zero or even negative marginal valuation as the costs of trimming may offset any price put on fat trimmings. The model could be further refined to take account of too little fat; markets sensitive to intra-muscular fat or marbling etc.

Synthesis of the Value of the Pistola: The foregoing elements for valuing meat from most of the pistola less shank may then be used to arrive at the potential value of pistolas from a treatment as follows:

1. Use a standard scheme for cutting the pistola into its main constituent parts - boneless primal cuts.

2. Apply a fat valuation model to each of these primal cuts. When cuts from a pistola are all of acceptable fatness no valuation adjustment would be needed. The next simplest case would be when excess fat was removed and given a nil valuation, the weight of the cuts after trimming going forward for lean valuation.

3. Apply a lean valuation model using tests on meat from one or more cuts.

4. The combined fat and lean valuation might either indicate price discounts for each cut or the effective marketable weight of cuts. In either case data on each cut could be combined by applying market prices for each cut (as in the Annexe). There would be a small and

fairly consistent upward bias in these valuations due to the excess of processing costs over by-product value.

The developing trade in chilled primal cuts of beef, especially vacuum packed beef, provides a potential source of data for synthesising market valuation of carcasses. However, the trade in primal cuts will only provide usable data if:

1. There is agreement on standard cutting lines.
2. There are reference levels of fatness.
3. Prices for primal cuts are published with reference to the category of beef, e.g. heifer, style of cutting, and level of fatness.

The first two aims would seem to be practicable in view of experience in developing standards for cutting and trimming primal cuts for the French and German markets. Publication of price data could also be achieved.

Valuation of the Fore-Quarter

The fore-quarters could be valued in the same way as hind-quarters, however, its general utilisation suggests a rather simpler approach. Thus the fact that most fore-quarter beef will be either cooked slowly or manufactured, greatly reduces the importance of its texture and flavour. However, greater importance is likely to be attached to water-holding capacity and the proportion of connective tissue present. Perhaps differences of water-holding capacity and connective tissue have a fairly simple relationship to price adjustment for fore-quarter meat and a compensatory valuation model could be used.

Fat on the fore-quarter may be valued rather lower than on the hind where it may often be considered part of the meat. Thus a fairly accurate market valuation of the fore-quarter may be simply synthesised from the weight of lean, a price for lean taking into account its water-holding capacity and connective tissue content; and the quantity of fat priced according to the ratio of fat to lean.

Conclusions

The preceding sections have shown

1) The need to predict differences in the sums of money that are likely to be obtained for beef produced by different treatments or technologies.

2) The deficiencies of relying on what buyers offer for carcasses as a guide to their potential monetary value when account must be taken of the importance of the ultimate effects of new technologies on both the characteristics of the beef produced and the conditions of demand for beef.

3) The possibilities of synthesising the relative potential market values of carcass from different treatments. The potential market value being the sum of valuation of boneless cuts from the pistola less shank (C.A. 2.1.8.2), plus an estimate for the remaining boneless cuts of beef (forequarter plus hind shank), plus or minus the value of bones and trimmings possibly after an adjustment to cover processing costs.

4) The use of cuts as units for valuing meat in the pistola requires the establishment of cutting lines and reference levels of fatness for this area of the carcass if not for the entire carcass. Some success has already been achieved in this sphere.

5) Valuation of lean and fat may be done by applying data derived from each cut or group of cuts to models of the valuation process. The possibilities for using conjunctive models were explored while use was also made of continuous valuation functions.

Finally, it must be recognised that there are serious conceptual difficulties in trying to estimate the market value of output from a new technology. From the stand point of economic theory a new technology is likely to violate the assumption that the goods traded are the same from the buyers' point of view. Thus from being a problem amenable to the sophisticated theory of market value, the ground shifts to the uncertain field of new product development. However, a remodelling of economic theory has been proposed to relate the demand for a product with a new set of characteristics, to the demand for similar goods already in trade (Lancaster 1966).

This paper has endeavoured to provide a conceptual framework for tackling the many practical problems for predicting the market value of the products of experiments.

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ANNEXE 1: Proposed Jointing of Carcass With an Example of Weights and Values

Name of Cut			Main muscles in the cut	Example Data		
English -	French -	German		Wt.	Price @	Total Value @
				kg.	p/lb	
Strip-loin	Faux-filet	Roastbeef	longissimus dorsi	6.5	105	£15.04
Rump*	Rumsteck*	Hüfte*	glutaeus medius, biceps femoris*	8.2	85	£15.36
Topside	Tende de Tranche	Oberschalle	semimembranosus	11.0	60	£14.55
Silverside	Semelle	Unterschalle	biceps femoris, semitendinosus	9.7	50	£10.69
Knuckle	Tranche grasse	Kugel	vastus lateralis, rectus femoris	7.2	53	£ 8.41
Fillet	Filet	Filet	psoas major and minor	3.1	150	£10.25
Cube roll	Entrecôte	Hochrippe	longissimus dorsi, trapezius	5.6	50	£ 6.17
Pistola less shank				51.3		£80.47
Remainder of meat				70.6	30	£46.68
Total Cuts				121.9		
Bones				30.2		
Trimmings	Fat**			14.1		
	Other			4.1		
Total Side **				170.3	33	£127.15

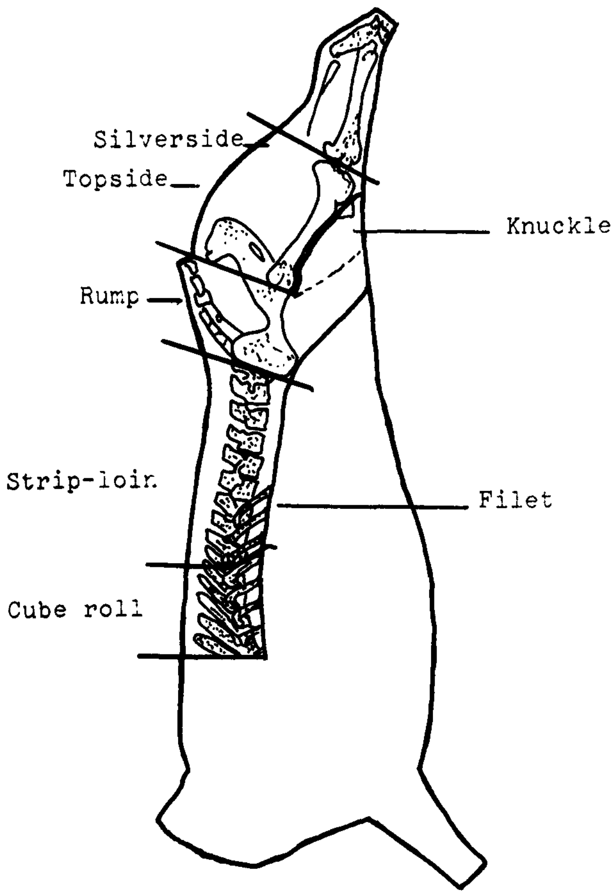
* includes:
gooseneck aiguillete baronne nemenlos M. tensor fasciae latae

**excluding cod fat

@ pricing in London mid-July 1975.

ANNEXE 2: Primal Cuts in the Pistola Less Shank of Codex Alimentarius

I/7.2.8



DISCUSSION ON SESSION 6 ON "RELATIONSHIPS BETWEEN MARKET VALUES, DISSECTION DATA, CARCASS CLASSIFICATION AND MEAT CHARACTERISTICS"

Discussion leader: H. de Boer.

Questions on specific papers

P a p e r b y H a r r i n g t o n

I. Schön: What are the contents of fat and muscle for classifications 5:5 and 1:1?

Harrington: The averages are given in table 5, but breed will affect the exact figures.

De Boer: Presumably classification has a low predictive value?

Harrington: Yes, it is difficult to judge under commercial conditions.

I. Schön: Does one find conformation 1 with fat class 5?

Harrington: Table 3 shows that none of these are found.

L. Schön: How many carcasses contributed to the averages in table 5?

Harrington: The number would be between 700 and 900, all of which were dissected.

P a p e r b y R i o r d a n

Williams: A recent paper by Harries et al. in 'Animal Production' (Harries, J.M., D.R. Williams and R.W. Pomeroy, 1975. Prediction of comparative retail value of beef carcasses. Anim.Prod.21:127-137) is relevant.

Tayler: What were the results of the experiment with young bulls which you referred to?

Riordan: Colour and pH were studied by Carroll, Joseph and Hood. Our own and a German carcass classification were used and Joseph referred to the results of a consumer test. In Germany the meat was braised and served to 400 people. There was a problem of high pH of the meat, following commercial slaughter. Many of the carcasses fell into an acceptable range of fatness.

General Discussion

Harries: Referring to the recent paper in 'Animal Production' this was assessing the retail value of 72 carcasses. It was assumed that they were sold at the same price but how much is fat allowed for? Much fat is sold at the same price as lean. Multiple correlations were calculated between retail value per kg and the percentages of lean and fat as independent variables, giving a value R = 0.987. Recently, 132 carcasses gave a similar high value. Harrington's figures show a range from 67 % to 61 % lean, so there is still a big difference in value within classes.

Riordan: The level of fatness illustrated by photographs was used to set up a specification in our work. Excess fat would be wasted.

De Boer: Riordan's paper is a useful approach to different markets. Harries' paper shows that lean content is a main determinant of carcass value.

Harries: Yes, but lean content and fat content are both important, and bone can be ignored in this.

Williams: The distribution of lean seems to be one of the least important factors.

I. Schön: In Harrington's paper, table 5 shows that the lean meat content for conformation class 5 and fat class 2 is relatively low. What was the percentage of fat in this class?

Harrington: The subcutaneous fat content is $4\frac{1}{2}$ % to $7\frac{1}{2}$ %. Table 4 shows that the average total fat content is 18 % (excluding kidney and channel fat).

Dumont: Regarding table 5, it is surely important to compare at the same carcass weight when making assessments?

Harrington: This table simplifies many variables. Conformation and fatness increase with carcass weight, but this has been examined statistically holding carcass weight constant.

De Boer: Proposals for further research were mentioned in Harrington's paper, e.g. on classification schemes. Their ultimate applicability is said to be dependent of national requirements. We must distinguish classification (descriptive) from grading (market value). The same classification could be applied to different markets. Harrington thinks some value should be attributed to meat quality in work on beef production, but this should not be over-emphasised and mainly focussed on tenderness.

Harrington: Other aspects were also referred to. More work is needed on the true importance of thickness of lean meat as distinct from weight and percentage. More work is also needed on shape and composition in relation to breed type.

De Boer: On the subject of thickness, do you mean evaluation in the market or how to define it?

Harrington: Yes, between breed type, shape and composition, as related to realisation value when the carcasses are cut and sold.

Harries: All the work referred to at the MRI assumed that the meat from a joint was sold at a retail price irrespective of thickness.

Harrington: There is no alternative at the moment.

Carroll: I support Harrington's plea for research on depth of muscle and its value in the market. Attention should be focussed on estimates in relation to composition of carcass. Muscularity is said to impart quality in the sense that the consumer likes a certain shape of joint or is it related to eating qualities? In some areas it is suggested that muscularity imposes a pattern on the distribution of lean meat. In France, differences in distribution are found between animals of low and high muscularity.

Kallweit: Harries referred to using the same price for joints, but there is a difference. Utilisation differs for thick and thin muscle, from processing if it is too thin to frying if it is thick.

De Boer: This difference in destination is true with big differences in thickness.

Bech Andersen: Regarding future research, what is going on in the common projects and how much carcass evaluation is there in these?

De Boer: There is a project on standard classification based on the EAAP standards, intended as a common project at this Institute and the Meat Research Institute, to compare breeds and systems in Europe in terms of the standards and of carcass yield and composition. We hope for co-operation on existing data. Dissection may be needed, to take this further. On Harrington's point regarding thickness of lean, no work is foreseen but it should be considered and, one hopes, carried out.

Part 7

CONSIDERATION OF POSSIBILITIES OF CO-ORDINATION AND OF REQUIREMENTS FOR FUTURE RESEARCH

3. The reference base to evaluate these methods should be complete carcass dissection into muscle fat and bone.

Dumont (session 3 "Assessment in the slaughtered animal and its carcass")
The important factors are:

1. W e i g h t o f c a r c a s s a n d o t h e r p a r t s o f t h e b o d y.
   The weight of the fifth quarter is important in many experiments, especially those on body composition in relation to feeding. The digestive tract and fat depôts are important as well as hide and head. Empty body weight is of interest. However, carcass weight is the most important measurement in many experiments and it is agreed that hot weight before washing should be recorded in a well-defined way.
2. A s s e s s m e n t o f t h e c a r c a s s. Visual assessments and linear measurements can be used. In the abattoir it is important to have complete appraisal by all the rapid and inexpensive methods which are available. Visual assessment is important here, and there are good EAAP references for fleshiness and fatness. These should be widely applied to clear up many points which have arisen in discussion. We need a clear idea of relationships between visual assessments, carcass measurements and the composition and distribution of tissues and lean: bone ratio. Verbeke's paper on blockiness and Harrington's on classification give instances where further research is required.

Cuthbertson (session 4 "Assessment of carcass composition")
An E.E.C. reference method of dissection is required not necessarily as a basis for our normal work but as a common base-line which could be applied to a sample of animals in all projects. At MLC we apply a commercial jointing and cutting procedure, but a sample is fully separated as a check on the commercial method. It is agreed that in nutritional studies, chemical composition is sometimes more appropriate, but a combination of this with physical separation should be useful. In other studies physical separation is the main method proposed, using a butcher's knife plus chemical analysis of tissues. Often, this could be preceded by a standardised commercial jointing procedure to assist in relating experiments to the commercial situation.
When full separation is not justified or resources are limited, prediction can be used, based on scores and sample joints. Much information on this already exists in different institutes and there is scope for extracting information

from these sources.

It is proposed that a small working group should be established to recommend procedures for standard jointing, separation and chemical analysis, for use if guidance is required. This could lead, in time, to the use of more common procedures. To study alternatives on many types of cattle, Institutes could be encouraged to answer questions which the working group might pose, so that gaps in our knowledge could then be filled.

Lis Buchter (session 5 "Assessment of meat characteristics, including sampling")

The assessment of meat characteristics has had little attention in the past. All the authors agreed that more work on the development of methods was needed. Important factors suitable for common action were:

1. The influence of preparation methods on meat tenderness, both shear force measurements and taste panel tests.
2. Assessment of colour characteristics including brightness and colour stability.

The discussion revealed the necessity for standard procedures and base-line methods so that meat quality results from different research groups can be directly compared.

Further problems were: a) whether animals should be exposed to standard or commercial conditions before measurements; b) the relationship between measurements and the demands from industry, retailer and consumer.

It is recommended that a working group is set up to discuss problems involved in meat quality assessments and to assist in the development of good base-line methods. It is suggested that the group starts by discussing the influence of preparation method on meat tenderness. Co-ordination of information in this area is much needed, and most member countries already have either experience or current local projects on this subject.

Béranger (session 1 "Carcass assessment in relation to experimental design")

In going through the conclusions of all sessions the following points of agreement could be assessed:

1. Serial slaughter technique will give the best assessment of weight,fatness, etc.
2. The determination of live weight should be precisely defined in all papers if it is to fit on a growth curve. In addition should be specified whether

slaughter weight is determined after fasting, etc.

3. Empty body weight is the most standard determination and should be measured by weighing the contents of the digestive tract. The content of the rumen and the whole tract and their relationship to each other needs to be established to simplify this measurement.
4. Carcass weight should be defined, e.g. hot, without washing; with or without kidney fat or tail. Tables of corrections could be drawn up, to convert from the standard carcass to the commercial carcass in each country.
5. Visual asssessments based on EAAP standards should be used. These show the type of cattle being used, in relation to standards.
6. Carcass composition determined by dissection is agreed, and a working group should define the method, and grouping of 'other tissues'.
7. When using indirect assessments in stead of total dissection, a small sample of animals should be completely dissected, to adjust the partial assessment, and the actual values should be presented for the samples. This applies to all types of experiment.
8. In nutritional and feed efficiency experiments both chemical composition of the whole body and physical composition should be measured directly or indirectly and related to each other.
9. Meat quality assessments should be further standardised, in particular the post-slaughter treatment in preparation for meat quality tests.
10. Co-operation between Institutes should be used to make good comparisons between different methods in common projects in which many cattle will be slaughtered and dissected. For example, ultrasonic and dilution techniques could be used if people wished to do this. The opportunity should be taken to compare methods when such large numbers of cattle are involved.

De Boer: Several useful suggestions have emerged. Two working groups have been proposed. Earlier Williams suggested a method of anatomical jointing and definition of which tissues should be grouped together. Also, a meat quality group had been proposed. Small groups working on such topics might receive EEC support to cover their costs. In addition planned common EEC research projects could be of use, e.g.

- the IVO/MRI project on the relation between classification and carcass composition and yield
- the CIVO project on meat quality characteristics
- the Kulmbach project on thermal influences on eating quality
- the Kulmbach project on stress influence on bull beef quality.

Further common research projects might emerge in addition to those already proposed.

Carroll: Session 6 should not be forgotten. It is recommended that we should consider the value of thickness of muscle in relation to retailer and consumer. This may vary between countries.

De Boer: I agree it is important, although no common projects have been proposed on this subject.

Tayler: Projects in national programmes can be included in co-ordination activities even if they are not in the common programme. They should not be excluded if they are relevant to the discussion.

Harries: Are there any results from the experiments on cooking at Kulmbach?

L. Schön: The work is proposed to cover various breeds, and criteria both on raw meat and after cooking, over a three-year period. The determinations will include amino acid and fatty acid composition, losses on roasting and cooking, sensory panel tests and histology, with 18 different muscles being used.

Riordan: We need more study of the relationships between studies of meat characteristics and the consumer acceptability of the meat.

Harries: agrees.

I. Schön: We prepare meat in a number of ways and make measurements both before and after cooking.

De Boer: With boar meat there is a big difference between taste panel and consumer results.

Riordan: In beef work in the USA it was found, with 100 consumers taken at random, when they compared preferences with laboratory methods, that the taste panel was a poor predictor and the Warner-Bratzler was better.

I. Schön: We have found good correlations between the two methods.

Buchter: We have found good correlation between our own taste panel and a consumer panel. But rather than taking a wide range of tasters it would be better to have a wide range of countries and eating habits represented, and not to rely on only one method.

Pomeroy: The problem raised by Riordan is only one facet of a much wider one. We too often attach importance to statistical significance in our results when the difference may be unimportant under practical conditions.

Kallweit: The papers delivered show a wide range of methods for meat quality evaluation which are often not exactly described and it is hard to achieve repeatable results. I suggest a collection is made of the methods used in beef quality evaluation before making an attempt to standardise them.

De Boer: I agree.

Buchter: This process could be speeded up if we request that accepted EEC projects should include plans and methods before starting the experiment, and that publication of the results should be started within one year rather than three or four years.

De Boer: Reports are required by the Commission before all the payments are made. The proposals have already given much information and the methods used were given in the questionnaire. Enormous variation was found. The follow-up should be to go through the questionnaires again and see what is relevant. There is a need to take action on this.

Tayler: It is desirable to standardise on the best methods and techniques of assessment where these are agreed, but caution must be exercised in this. It may not be desirable to attempt to standardise all aspects of projects in a common programme. Often the objectives are slightly different and different methods of experimentation are appropriate.

De Boer: Comparability of data can be improved by the use of additional methods such as the EAAP reference methods. Mutual consultation improves comparability of the results.

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