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ASSESSMENT OF BODY COMPOSITION IN THE LIVE ANIMAL

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SUMMARY

A review is presented of methods of estimating the composition of live animals. Conformation, body weight, external and internal linear measurements, body water, body density, electrolyte content (potassium-40) and other techniques are briefly discussed. The author concludes that no completely satisfactory method is at present available.

INTRODUCTION

THE ABSENCE of a method that permits the accurate evaluation of the composition of live animals is one of the most obvious deficiencies when research techniques available to animal production research workers are considered. If an animal breeder wishes to follow a programme for improving the carcass composition of meat animals, he has to have some criterion for recognizing the superior carcasses, while they are still walking around in a paddock as part of a live animal.

In most nutritional experiments it is desirable to have an estimate of the nutritional components and total energy stored within the experimental animals during the course of the experiments. An increase in precision would be achieved if this information could be obtained on the same animal at two stages of its life instead of having to use the present method of slaughtering sample groups at the beginning and end of the experimental period.

When serial measurements have been made on the same animals, the between-animal variation can be removed when tests of significance are made for treatment effects. This was pointed out by Harrington (1963) when discussing some statistical considerations involved in planning body composition experiments. Wood and Groves (1963) have recently shown that slaughter type growth experiments may result in smooth growth curves because of the effects of averaging the observations on several animals, whereas some of the individual animals may, in fact, produce quite fluctuating curves because of the possible phasic nature of growth under certain conditions. When working with the body composition of a human population, there seems to be a distinct prejudice against the slaughter type experiment and so, in this case also, the use of a non-destructive method is essential.

METHODS

Reviews covering many of the methods being currently investigated have been compiled by Harrington (1958) and Brozek (1961). This discussion will concentrate mainly on more recently published information, with particular emphasis on sheep.

CONFORMATION

Conformation or shape is a characteristic of live animals which is commonly included among the factors selected for in a farm breeding programme as an indication of the meat content, or composition, of the animal. Less attention has been paid to conformation in research projects. One of the major difficulties is that desirable conformation means different things to different people. In fact, a cynic has recently defined conformation as something which registered animals have and unregistered animals lack. However, few people would disagree that the only meaningful differences in conformation of live animals intended for meat production are those which reflect differences in the content and distribution of the major tissues and hence carcass value (Harrington *et al.*, 1963; Tayler and Rudman, 1963). A possible exception may be in the case of New Zealand lamb. The N.Z. Meat Producers Board believe that the blocky Southdown type of carcass has some intrinsic merit making it especially desirable to some British butchers.

At a technical conference on carcass composition and appraisal in meat animals held in Australia in August, 1963, the gathering decided that "The results of several investigations which employed advanced techniques indicated the limited usefulness of continuing to include body shape as a major factor in meat production experimentation and the Conference recommends that the matter should be the subject of further investigation". Similarly, the study commissions of the European Association of Animal Production meeting in Rome in August, 1963, did not consider that conformation was a useful criterion in carcass evaluation since its real significance has not been established. In the U.S.A. also, Butler (1957) noted "the main conclusion reached from carcass studies in the Meats Laboratory of the Texas Agricultural Experiment Station is that the animal breeder has considerable latitude in selecting animals of different shapes without encountering great changes in the proportion of wholesale cuts. This does not discount the saleability of good conformation by present standards".

Harrington *et al.* (1963) planned an experiment in which experienced live-animal judges were asked to rank some live pigs in order of yield of lean cuts and also separately in order of increasing area of the eye muscle. The pigs were then slaughtered and the characteristics were measured on the carcasses. The results of the experiment showed that the experienced live-animal judges were very inaccurate in predicting the economic characters that were measured.

Thus, the available evidence questions the usefulness of conformation as an indicator of animal composition.

BODY WEIGHT

An estimate of the composition of animals can be made from their liveweight. Equations for computing the dissected fat, muscle and bone content of the dressed carcasses of sheep from their empty liveweight have been published by Tulloh (1963) and similar equations were shown for pigs and cattle (Tulloh, 1962). The equations covered the weight range from birth to maturity, whereas in practice the problem is usually to distinguish between the composition of animals over a small range in weights (*e.g.*, at slaughter weights). The equations were based on empty liveweight (body weight minus the contents of the gastro-intestinal tract) which, up to the present, cannot be measured on the live animal.

Bensadoun *et al.* (1963) and Reid *et al.* (1963) have shown that the shrunk body weight (weight after 18 to 20 hour fast) of sheep is almost as closely related to empty body water as are the dilution spaces of some chemicals which have been used to estimate this body compartment. Kirton (1957) showed that the correlation between body weight and carcass fat in Romney ewes was lower (0.71) than the equivalent carcass weight correlation (0.91). Orme (1963) has reported a large number of low correlations between liveweight and measures of carcass composition of sheep.

Some of the limitations of the use of body weight and body weight change in relation to the composition of ruminants have been discussed by Tayler *et al.* (1957) and

Reid *et al.* (1963). The former workers showed that "fill" could obscure the trend of carcass gain or loss in ruminants and the latter group have pointed out that the ingesta of the gastro-intestinal tract can comprise 5 to 30% of body weight and can be altered by nutritional treatments. It can therefore be seen that body weight is a very useful measurement to record, but it must be interpreted with caution. If a practical means can be devised for measuring the alimentary tract contents of the live animal, then body weight will be an even more useful indication of animal composition than is at present the case.

External Linear Measurements

Such measurements are undoubtedly of use for descriptive purposes, although it has yet to be shown that they are of any use for indicating body and carcass composition. An important factor limiting the usefulness of live animal measurement is the actual measurement errors involved (Taylor, 1963). Lush and Copeland (1930) contended that, "the principal objection to the extensive use of body measurements seems to be not their inaccuracy but their inadequacy to describe the animal in a complete way. . . . For most purposes a very few measurements considered in relation to each other or in relation to weight seems as much as would be really useful in contributing to the general picture of the animal and of the changes that occurred in it". The literature relating linear and weight measurements to the carcass composition of the common meat animals has been reviewed by Russel (1961). His review showed that, in general, weight measurements were more closely related to the yield of carcass components than were linear measurements. Similarly, Tayler *et al.* (1961) and Orme (1963) have shown that linear measurements contribute very little towards increasing the accuracy of the prediction of body (or carcass) composition if the information from body or carcass weight is used.

Internal Linear Measurements

The measurements often taken include subcutaneous fat thickness, longissimus dorsi (eye muscle) depth and longissimus dorsi area at some definable location (it is hoped) on the live animal. When subcutaneous fat thickness is recorded, an attempt is being made to use a one-dimensional measurement (which is a sample of the many such measurements that could be taken) to describe a three-dimensional layer of fat of variable thickness plus other carcass fat — that is, this measurement is often used as an index of total carcass fat. It is not surprising that the relationships observed between backfat thickness and total fat are not very good from a predictive point of view. However, as backfat thickness is in itself a useful measure of a factor of economic importance (being related to consumer acceptance) it would be helpful to be able to measure it on the live animal.

Although several methods have been used to measure backfat thickness (leanmeter, thermistor probe, metal ruler, ultrasonics, etc.) in cattle and pigs, only the use of an 18 gauge probing needle and the leanmeter have been reported for sheep (Matthews *et al.*, 1960; Ulyatt, 1960). The big problem with backfat measurements on the live lamb appears to be the small thickness of subcutaneous fat present and its comparatively low variation (in contrast to pigs). This is probably the explanation for the absence of reports on the use of ultrasonics to measure the backfat thickness of live sheep, although the method has been tried for the longissimus dorsi area in this species (Campbell *et al.*, 1959; Zobrisky *et al.*, 1961). Ultrasonic measurements appear to be more accurate for predicting the backfat thickness of pigs and are less accurate for cattle (Price *et al.*, 1960a; Alsmeyer *et al.*, 1963; Stouffer, 1963). Some of the disadvantages of the use of the ultrasonic method for estimating longissimus dorsi area have been discussed by Price *et al.* (1960b), but improved equipment (Stouffer, 1963; King, 1963) may eventually overcome some of the inaccuracies of the technique.

Body Water

Many workers have shown that the composition of the fat-free bodies of many species of animal is relatively constant when allowance has been made for age and abnormalities (Harrington, 1958; Symposium, 1961; Symposium, 1963; Panaretto, 1963a,b; Bensadoun *et al.*, 1963; Panaretto and Till, 1963). Therefore, once the fat-free body has been estimated, body fat can be predicted by difference if the fat-free body is subtracted from body weight. Some allowance for changing composition with age can be made if the regression relationship between body water and body fat is computed from chemical data on an age series of animals of the species of interest.

The key to the resolution of body composition in the live animal lies in the accurate estimation of one of the major body components, and the one usually chosen is body water. This can be measured by injecting a known amount of some marker substance and measuring its degree of dilution in a sample of body fluid if the substance is completely and evenly distributed throughout that fluid. A scheme for resolving the body composition of ruminants using antipyrine as the marker substance to measure body water has been presented by Bensadoun *et al.* (1963) and Reid *et al.* (1963). Other research workers (Panaretto and Till, 1963) prefer the use of tritiated water because it gives a better absolute estimate of the amount of body water present (when compared with antipyrine). However, the tritiated water technique suffers the disadvantage that the treated animals must be destroyed at the end of their experimental lives.

Reviews of the methods of measuring body water and some of the refinements for partitioning this body component into several fluid compartments have been given by Edelman (1961) and Panaretto (1964). Methods and equipment necessary for body water determinations on a routine basis are still being improved and the most important query remaining to be answered is whether sufficient accuracy can be achieved to make the methods useful for experimental purposes.

Body Density Measurements

As was mentioned in the previous section, for the purpose of a simple approximation, the animal body can be considered as consisting of two components; fat and fat-free body. Because the fat-free body has a relatively constant composition after allowing for age changes (for some of the pitfalls in these assumptions see Behnke, 1961; Brozek *et al.*, 1963; Wedgewood, 1963) it is not surprising to find that this constituent has a relatively constant density. Similarly, fat also has a relatively constant and lower density. Because the body has been found to consist of these two components of different densities, it has been shown that, the lower the proportion of fat in the animal body the higher is its density, and the higher the proportion of fat the lower is the density.

In order to measure the density, two observations are necessary — the mass and the volume. Although the weight of an animal is quite easy to obtain, the problem of measuring the volume of an irregularly shape body which contains gas-filled cavities (lungs and intestines) has proved to be very great. In the eviscerated carcass the volume is determined by the water displacement method (see review of Holme *et al.*, 1963) as has also been done on humans (who will co-operate by holding their breath and for whom an estimate of lung air volume can be made; Brozek, 1961; Buskirk, 1961).

Because of the discomfort to the subject of the water displacement method, and because of its limited applicability to farm and laboratory animals, other methods of measuring volume have been developed which involve the use of air displacement (Loh, 1956; Liuzzo *et al.*, 1958; Gnaedinger *et al.*, 1963; Falkner, 1963; Lim, 1963) or gas, usually helium, dilution (Behnke, 1961; Siri, 1961; Fomon *et al.*, 1963; Gnaedinger *et al.*, 1963). When Gnaedinger *et al.* (1963) attempted to relate the body density of live pigs to their directly determined composition, no significant correlations were obtained. Reasons for this and measurement problems encountered were discussed. Subsequently Hix and Pearson (1964) using the same apparatus but with better control of temperature conditions have recorded very high correlations between the density of humans determined by the helium dilution and air displacement methods. The use of the "suppressed zero" system (Loh, 1956) might further increase the accuracy of volume determination by the method of air displacement.

An interesting piece of apparatus has been designed by Beeston (C.S.I.R.O., Prospect, N.S.W.) to measure the volume of sheep in a minimum volume of air. He has attempted to reduce the measurement problems caused by the effects of changing air temperature and humidity on air volume. The results relating the specific gravities of 14 sheep to their directly determined body composition post slaughter appeared promising (Beeston, pers. comm.) and an interesting technique was also developed for determining the specific gravity of sheep homogenate. Tallis *et al.* (1963) have attempted to determine the specific gravity of live Merino wethers by underwater weighing but unfortunately the experimental details of the method were not described. A brief report has also been given of another system (Kay and Jones, 1962) for measuring the volume of live pigs (underwater weighing with helium dilution to determine head and lung volume) with apparently promising results.

Thus several methods are being investigated for determining the composition of live animals from their density.

It remains to be seen whether there is a sufficiently close relationship between body density and fatness to make the former parameter worth measuring and whether the volume can be measured with sufficient precision to give the prediction of body fatness with acceptable accuracy.

Electrolyte Content

One of the more recent methods that is currently being investigated for the prediction of the composition of living animals involves the estimation of their potassium (Kirton, 1964; Symposium, 1963), sodium (Edelman, 1961) or caesium (Kulwich *et al.*, 1961a,b; Pfau *et al.*, 1961) contents either individually or in combination. Potassium is usually found in the intracellular fluid of mammals (as is caesium-137, one of the products of nuclear weapons testing) and sodium is mainly found in the extracellular fluid. The measurement of caesium-137 would appear to give the least accurate estimate of body or carcass composition.

Most interest has been shown in the estimation of the potassium content because of the naturally occurring radioactivity of potassium-40 and the development of gamma radiation detectors capable of measuring the low levels of radioactivity present (Anderson and Langham, 1961). Anderson (1959) stated, "Since the concentration of potassium in living cells is held constant by homeostatic processes, a determination of potassium content is equivalent to a determination of cellular mass. There is no potassium in fat and very little in bone. . . . Applications to the meat industry are based on this proportionality between potassium and mass of lean tissue". In other words, the higher the proportion of potassium in an animal or its carcass the higher will be the proportion of muscular tissue (and the lower will be the proportion of fatty tissue), and the lower the proportion of potassium the lower will be the proportion of muscular tissue (and the higher the proportion of fatty tissue).

Potassium-40 comprises a small constant proportion of all naturally occurring potassium and the gamma rays emitted by this isotope are the main source of radioactivity in most living material. They are capable of escaping from an animal body. Therefore, if a gamma detector is placed beside (crystal scintillometer) or around (whole body counter) an animal body, it is possible to measure the radioactivity and calibrate this in terms of weight or percentage of potassium present. From these radioactivity measurements and previously determined relationships between potassium content and body composition, the composition of other animals of the same age and species can be estimated. The many factors known to influence the potassium content of living animals and some of the difficulties in using potassium relationships for the prediction of the composition of farm animals have been reviewed by Kirton (1964). Mention should also be made that the equipment for potassium-40 determinations is very expensive.

An alternative procedure of adding radioactive potassium and sodium isotopes and after equilibration, withdrawing samples of body fluid to determine the degree of isotopic dilution, has not been used in farm animals as a method of determining their electrolyte content, and from this their composition. A little evidence is available to suggest that the estimation of sodium and potassium in combination could increase the accuracy of prediction of body composition over the use of potassium alone (Kirton *et al.*, 1963).

Other Techniques

Monophotogrammetry (Pierson, 1961, 1963) and stereophotogrammetry (Leydolph, 1963), which employ the principle of photography as used in contour mapping, have been tried for determining the external volume of live animals. If these methods are to be used for density determinations, the problem of measuring the volume of lung and intestinal gas remains after the method has been sufficiently developed for experimental application.

Another method of interest, which may be used for the determination of the fat content of live animals, is based on the absorption (by fatty tissue) of inert gasses (Lesser and Zak, 1963). A disadvantage of the method from the point of view of animal experimentation is that the subject must be exposed to the gas in a closed circuit apparatus for from 2 to 8 hours.

The biopsy and core technique may be particularly suitable for farm animals (Everitt and Carter, 1961; Bray, 1963), although from the point of view of quantitation of the composition of meat-producing animals, the latter workers pointed out the limitations due to the problem of selecting a representative sampling site.

CONCLUSIONS

Experimental results to date suggest that at present there is no completely satisfactory method of estimating the composition of live animals, although several methods look promising. An increase in the accuracy of prediction could come from further improvement of techniques currently being investigated, from new techniques, for from a combination of the results of two or more of the methods by the use of multiple regression (Harrington and King, 1963).

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DISCUSSION

DR G. R. MOULE: In Australia, people have realized the difficulty of assessing body condition and conformation, and present feelings are that some other criteria such as total body cell mass should be determined, together with liveweight, which itself is quite labile.

DR A. H. CARTER: *Despite the advantage in terms of simplifying breeding objectives of being able to discount unimportant factors, I am not convinced that conformation is in fact quite unimportant.*

Conformation has been virtually the only factor used in the past in developing the improved meat breeds, and there appears little doubt that improvements over the original breed types have been made. Would the speaker not agree that the problem is not so much that conformation is unimportant but that we lack objective criteria of measuring it?

DR A. H. KIRTON: As Dr Carter suggests, we lack objective criteria for measuring conformation. This is not surprising as conformation is defined in different ways by different people and many prefer to leave it undefined. In terms of breeding objectives, we can define and measure factors of known economic importance such as growth rate and carcass value and these would, therefore, appear to be of greater use than conformation in an improvement programme, unless someone can show that conformation is more closely related to some important economic characteristic than the previously mentioned factors. In the light of recent evidence from the U.S.A. and Australia with reference to the amount and distribution of red meat in the "unimproved" breeds of cattle such as the zebu when compared with the improved British breeds (such as the Hereford and Angus), there is now considerable doubt as to whether any improvement has been achieved in the "improved" breeds of cattle. These doubts have been increased when cutting tests in Britain and the U.S.A. have shown that some dairy breeds of cattle (*e.g.*, Friesian) are as good for beef production as the "improved" beef breeds (Branaman *et al.*, 1962, *J. anim. Sci.*, *21*: 321; Callow, 1961, *J. agric. Sci.*, *56*: 265).

PROFESSOR I. E. COOP: Conformation is more than just a proportion of cuts. The lamb of good conformation has lower surface/volume ratio than one of poor conformation and so would lose less moisture during transport, storage and cooking. Nevertheless, I entirely agree that the pendulum must swing in the direction of lesser significance of conformation provided it does not swing too far. Referring to the relationship between liveweight and conformation and body composition in fat lamb, it is my experience that, provided I have weighed the lamb, I am a much better lamb drafter than any of the professional lamb drafters I have so far employed.

DR KIRTON: While agreeing that conformation is more than just proportion of cuts, I am not aware of any work contrasting the surface/volume ratio of animals of good and poor conformation. I agree that, as long as we ship our lambs to Britain as frozen entire carcasses, we may need a minimum of fat cover to prevent dehydration in transit. However, it is interesting to note that, in a recent experiment on the eating characteristics of lambs of good and poor conformation, there were no differences in the cooking losses from the different types (Boccard and Radomska, 1963, *Ann. Zootech.*, *12*: 5). I agree with Professor Coop that drafting can be done more accurately with a set of scales, than by eye and hand alone.

Q: *Using the potassium-40 technique, is there any probability that results might be prejudiced by the amount of radioactive fallout to which the animal had been exposed?*

Dr Kirton: Fallout is unlikely to be a problem. Beta-ray emitters (*e.g.*, strontium-90) will not be detected by whole body counters and most gamma-ray emitters are eliminated by limiting the range in the gamma spectrum within which counts are recorded (see Kirton, *et al.*, 1961, *J. anim. Sci.*, *20*: 635).

C. L. Sandbrook: *Does not Ruakura experience confirm Dr Kirton's disbelief in conformation as a valuable criterion? The 18-month-old Jersey × Angus crossbreds sent to London some years ago were reported both by meat inspectors here and in U.K. to have poor conformation, yet Lyons testing and cutting service reported excellent lean meat yield.*

Dr Kirton: Dr McMeekan reported the results mentioned at the 1956 Ruakura Farmers' Conference. Using eye appraisal, both New Zealand and British carcass judges were critical of the Jersey × Angus carcasses but J. Lyons and Company submitted the carcasses to cutting and palatability tests and found they compared quite favourably with standard New Zealand baby chilled beef and Argentine chilled beef.

Q: *Is there an association of conformation with growth rates to killing weight, in the meat animals. In other words, if less attention is paid to conformation, might some efficiency of food conversion be lost?*

Dr Kirton: I am not aware of any evidence showing such an association. However, it would seem more logical to select directly for growth rate and killing weight which can be defined and easily measured, rather than some factor which might be associated with them. Overseas evidence tends to suggest that faster growing animals are also more efficient converters.

Q: *Development of a practical method of estimating body fat seems a most desirable project. Could Dr Kirton say whether he expects to continue work on possible methods?*

Dr Kirton: I hope to continue working in this field if I can gain access to some of the facilities necessary. Much of this sort of work is at present very expensive.

Q: *Would the figures quoted for percentage of fat, solids, water and gut in the carcass be the same for all ages and weights of animal?*

Dr Kirton: The figures quoted in the diagram, which do not appear in the printed proceedings, are known to vary with age, state of dehydration and state of health of the particular animals as well as with many other factors. The preferred procedure is to use previously determined regression relationships between body water and other constituents rather than considering water as a constant fraction of the fat-free body.