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by

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Until recent years little attention has been directed in New Zealand to objective experimentation in meat production. Indeed very little research of any kind has been carried out in this field. With an increasing number of workers becoming concerned with research involving meat producing animals as well as with meat production itself, the time seems opportune to attempt at least some degree of unanimity on the principles which should govern such studies. It is with the object of assisting towards this end that the observations in this paper are advanced.

At the outset it should be understood that the views of the writer on technique aspects of meat production are conditioned to an important degree by what may be termed the 'growth approach' to animal production (Hammond - 1932). It is well established that the characters upon which the value of any meat animal depends are fundamentally the result of differential growth and development changes occurring within the body. Differences in rate, order and extent of development of particular parts and particular tissues are responsible for the differences in form, in anatomical, histological and chemical composition and structure of individual animals, of animals of different weights, breeds and even of different species. Furthermore, hereditary and environmental influences exert their effect upon the animal body by controlling and modifying differentially the growth gradient mechanism (McMeekan - 1940/41).

This philosophy conditions technique more particularly through its influence upon methods of measurement of treatment effects and upon certain aspects of design.

Meat production research may proceed along two main lines:- by the use of the survey technique and by objective experimentation. The former involves the collection and statistical analysis of mass data of a relatively coarse type. It has its most important function in pointing to profitable lines of objective research. It is specially suited for defining the existing status of meat production in respect of the many factors such as breed, cross, district, climate, nutrition and management methods contributing to its efficiency. Under special conditions it may have limited use in evaluating the influence of specific factors affecting production (Palsson - 1940; Hirzell - 1939; and Bonsma - 1939 for sheep. Hammond and Murray - 1937; McMeekan - 1937 for pigs). In general terms, however, it is unsuited for any precise evaluation of individual factor influence. This is the function of the objective experiment where all variables other than those under investigation are controlled, and where more precise measures of effects can be employed.

Detailed considerations of technique are conveniently approached from the three main angles of:-

- (1) Methods of measurement.
- (2) Experimental material.
- (3) Experimental design.

1. METHODS OF MEASUREMENT:

In both general lines of attack, methods of measurement are of primary importance, in consequence of which much effort has been devoted of recent years to investigating and establishing suitable techniques. It should not be necessary to emphasise that any critical work on meat production must be carried to the post slaughter stage. The animal as a whole is the resultant of differential growth of its constituent parts. Its value for meat purposes in any market depends basically upon the proportion of the various parts of the carcase and upon its relative composition in terms of bone, muscle, fat and offals, so that effective measurements of these characters is essential for comparison with

standards obtainable from specific markets (Davidson et al - 1936; McMeekan - 1939).

This may be achieved by carcase measurements, by the use of sample joints or by complete anatomical dissection. In addition, photographic methods have a supplementary value.

Carcase measurements of an arbitrary type have long been employed as a logical means of objectively describing body form. Palsson (1940) for sheep and McMeekan (1941) for pigs have justified their use on quantitative grounds, demonstrating their usefulness as indices of carcase composition. In both species high correlations of the order of $r = +0.75$ to $r = +0.96$ have been shown to exist between certain appropriate internal and external measurements and the total weight of bone, muscle and fat in the carcases of lambs, hoggets and bacon pigs. Regression equations permitting the calculation of the weight of the major tissues have been developed in the case of measurements showing highest correlations with particular tissues. For example the total weight of muscle in the bacon pig may be calculated from the formula $Y = 189 X - 10180$ grams where Y = total muscle and X = the length plus the depth in millimetres of the longissimus dorsi measured at the loin region. In this way over forty different body measurements have been evaluated in the two species. Concentration on measurements thus shown to have a quantitative basis, is suggested in comparative slaughter work relying upon the carcase measurement method of evaluating results. Indeed, provided these quantitative measurements are employed there is little need to go past this technique for most classes of work.

Carcase measurements are the only criteria that can be employed with the survey method, when data more critical than mass grading results are required. It should be emphasised here that linear measurements on the external surface of the body are reliable guides to skeletal development only. Carcase measurements aiming at providing indices of muscle and fat tissues must be obtained from a cross section surface and therefore involve cutting the carcase. This is unavoidable. For more critical work, the technique of employing sample joints which may be conveniently dissected into their constituent parts in the laboratory, has many advantages. The leg and the loin joints have been established in both pigs and sheep as specially suited for this purpose. Their boundaries may be fixed by well defined skeletal points so that sampling errors are reduced to a minimum; they provide a picture of the most valuable part of the animal; the loin, as the latest developing region of the carcase, provides a picture of carcase strengths and weaknesses; the leg bones and muscles provide opportunity for the study of differential growth phenomena within, as well as between, tissues; while the composition of these two joints together or separately provides an accurate index of the composition of the whole animal. Correlation co-efficients closely approaching unity, the order of $r = +0.94$ to $r = +0.97$ exist between bone, muscle and fat of these joints and the total weight of these tissues. Regression functions developed for the purpose permit estimation of carcase composition with a high degree of accuracy (McMeekan - 1940/41 for pigs; Palsson - 1940 for sheep).

It is very important to emphasise at this point that while the principles involved here are well established, the precise mathematical relationships obtained will not necessarily apply to animal populations other than those from which they have been derived. Comparable foundation work is required for each population worked with.

Hammond has been responsible for developing the complete dissection technique in which the animal is dissected in the laboratory into its constituent anatomical units. The method is extremely laborious and costly, involving a large amount of skilled labour. Its usefulness is confined to the most critical types of work; to fundamental experiments aiming at the enunciation of principles; to foundation experiments aimed at justifying, for

example, the basis of measurement and sample joint technique mentioned above. The method is the modern equivalent of the complete chemical analysis technique of Lawes and Gilbert (1858), and the rough 'butcher' dissection of American workers. Chemical analysis of carcases has little relationship to meat quality (McMeekan - 1940/41), while 'butcher' dissection is too rough for critical work. Callow and his co-workers (1935/40) have shown that adequate chemical data can be obtained from suitable sampling methods. These provide valuable supplementary information to the anatomical side. As part of any dissection technique, useful histological data relative to tenderness, and cooking quality should be obtained. Complete description of the technique is given for sheep by Palsson (1940) and for pigs by McMeekan (1940).

Mention was made that carcase measures are often used to describe form or shape which is an important quality factor in meat production. While superior to measurements on the live animal which suffer from grave errors on the score of repeatability, carcase measures are not entirely satisfactory in describing shape since the quality differences involved are not concerned with plane surfaces. Since, also, we are here concerned mainly with relative differences in form, of animals frequently differing in size, the camera is a useful device permitting comparison on a basis of one standardised part. Comparisons of animals scaled to the same 'height at withers' for example provides a much better picture of relative development than comparisons on an actual size basis. Hammond has exploited this technique very fully and profitably in many publications. It is specially useful in demonstrating the relative development of early and late developing parts.

11. EXPERIMENTAL MATERIAL:

Work with cattle, sheep and pigs is slow, laborious and costly. Normal populations of stock are subject to such a high degree of variability that significant results can be obtained only by the use of large numbers of animals and/or by frequent replication when treatment differences are small as must often be the case. The literature abounds with examples of inconclusive results in consequence of the masking effect of variability in material. Apart from special methods referred to later, little can be done in experimental design to overcome the difficulty. The usual methods of 'balancing' experimental groups on a basis of criteria such as breed, breeding, age, sex and live weight frequently fail to increase experimental precision to any significant degree (Dunlop - 1933; Woodman et al - 1936) though as a general rule it pays to take such precautions when employing commercial stock.

The development of uniform stocks of animals by inbreeding provides a possible alternative. This approach is being attempted by the writer with both pigs and sheep. As a means of securing uniformity inbreeding has already been successfully exploited in the rat (Wistar Instit.) and the rabbit (Hammond). The experiments of the writer with the Cambridge strain of inbred Large White Pigs (McMeekan - 1940/41) are promising. A potential weakness is that results with inbred stock may not be applicable in precise terms to average populations. This, in some measure, is also characteristic of any experimental results with any set of animals since there is normally no certainty that the stock used constitutes a random sample of the population. Rather is the reverse likely to be the case, since every effort is usually made to reduce variability characteristic of the population, by selection on a basis of the criteria mentioned above in 'balancing' experimental groups. In any case the criticism does not hold so long as inbred material is employed for the purpose of enunciating general principles, in determining the nature and trend of specific treatment effects, rather than for the measurement of precise commercial or field effects.

Another line of attack worth consideration is the use of laboratory animals. Though not employed as yet in meat production studies in New Zealand, such material as 'pointer' animals holds definite promise. Much wasteful experimentation might be eliminated if experiments were carried out first on the rat or the rabbit in such a way as to point to profitable work with larger species. As an example the prelude of the work of the writer on the shape of the growth curve as a major factor in the form and composition of the animal body (McMeekan - 1940/41) was that of Dunlop (1937) on the relative growth of the rabbit's ear.

III. DESIGN IN EXPERIMENT:

The aim of objective experiments is the attainment of clear cut, significant results in precise terms. This can be secured only by suitable design. There is no doubt that much abortive work has its origin in ill planned experiments. At one time there was perhaps some excuse for this. While considerable attention had been devoted to effective design in plant work, the special problems of animal experimentation received little notice. Of recent years, however, an extensive literature has developed on the subject with which it is incumbent upon all workers - especially those responsible for administrative planning - to become familiar.

Details of design will necessarily vary with the nature of the specific problems under attack but the general form, plan or layout of an experiment should embody certain principles. To secure the objective mentioned above - the attainment of clear cut results in precise terms - any critical objective experiment in meat production must be so designed as to permit the application of recognised tests of statistical significance to measured treatment effects, preferably by the analysis of variance technique. There still exists amongst New Zealand workers too little appreciation of this fundamental requirement; there are too many of us who claim that if experimental results are not obviously clear cut they are of no practical significance and can therefore be ignored. This attitude would be reasonable were it not inevitably associated with poorly designed methods of experimentation. Unfortunately, the great bulk of factors involved in animal production tend to be small in the individual but large in their cumulative and associative effect upon the animal. Their investigation necessitates the use of small treatment differences and the employment of highly sensitive designs which only an appreciation and application of statistical methods can provide. In this connection I would stress that there is no justification for the common belief that an understanding of the idea and use of analysis of variance is beyond the comprehension of average intelligence. Research workers who refuse to familiarise themselves with its implications are running away from their jobs.

The application of statistical principles to design involves immediately considerations of group, paired and individual feeding; of the number of animals required; of the number of variants per experiment; and of the extent of treatment differences.

The use of group feeding and management technique is suited only to the coarser type of experiment where either treatment differences and/or number of animals are large. It is specially unsuitable when more than one factor or variable is involved. Most meat investigations of necessity involve consideration of food consumption. The impossibility of controlling and measuring individual intake of group fed animals is the major drawback to the method, leading to marked lack of sensitivity and the inability to apply the more precise statistical tests. In contrast, the individual feeding system by permitting control of intake, increases sensitivity approximately four times (Woodman et al - 1936). It further enables the application of a 'latin square' or equivalent design (see papers of Dunlop - 1933; Woodman et al - 1936; McMeekan - 1940/41; Verges - 1940) and permits of the simultaneous investigation of two or more factors, and the segregation of the individ-

ual and interaction effects through the use of analysis of variance and co-variance. By careful design animal experiments can be every bit as accurate and sensitive as field plot trials in plant work. For example Woodman et al (1936) obtained a standard error per pig of 6.5 per cent. of the mean and the writer (1940) standard error as low as 3.9 per cent of the mean - figures comparing more than favourably with figures of 4 - 8 per cent for standard error per plot in modern replicated experiments in agricultural crops (Wishart and Saunders - 1936).

The 'paired system' is specially suited to the investigation of single factors and is merely a specialised adaptation of the individual method.

Despite its disadvantages the group system has certain merits on practical grounds, since in the field, animals are fed as groups. Woodman (1937) for this reason suggests and uses the two in conjunction in all experiments with pigs. Carroll, Lush and Crampton (1930) discuss fully the relative merits of these three methods.

Summarising the position it is suggested that the individual method should be employed whenever critical work is required; where principles rather than purely practical objectives are sought; and where considerations of material, labour, cost and time limit the number of animals capable of being dealt with. The group system should be confined to large scale field work; to checking up the results of the more precise laboratory method, and to conditions where cost considerations are not acute.

Considerations of number and selection of animals are of great importance. The number required per treatment depends on two main factors; the variability in the animals concerned and the extent of the treatment differences to be employed. The former, as already suggested, may be reduced by inbreeding, while extremes of treatment difference can be an effective device in reducing the number of animals per treatment. By the latin square design, by the use of inbred materials and by the imposition of extremes of treatment difference, the writer has reduced the number of animals per group to five and still obtained highly significant results, (McMeekan - 1940/41). This is about half that normally suggested as a minimum for most types of animal experiments. Knowledge of statistical variance of populations of stock under test can be employed to determine the number of such stock constituting a representative sample (Fisher - 1934) providing thereby a reliable estimate of the number needed and a guide to the most effective design. This device is also very useful in determining the number of test animals for breeding experiments. For example, Lush (1936) arrives at a figure of four pigs per litter as an effective sample, while McMahon (1940) suggests a figure of seven progeny as adequate to provide a sample of an individual ram's get. Similar estimates are available in respect to dairy cattle. There is definite need for data on normal variance in stock populations in New Zealand as a guide to experimental design. On the selection side, as already indicated, treatment groups are usually 'balanced' for major variable factors as breed, breeding, sex, initial live weights and age. The importance of some of these is debatable. In many cases an insistence on their inclusion as criteria in selection and balancing sometimes needlessly complicates design and may react detrimentally upon, or at least add little to, the sensitivity of certain types of experiment (Woodman - 1936). For most types of meat work, however, especially when carried to the post slaughter stage, standardisation for sex and breed is essential owing to the major effect of these two factors on body form and composition (McMeekan - 1940/41; McMeekan and Wallace, unpublished, and Verges - 1940). Differences in initial live weights can be adjusted by co-variance providing the experimental design permits the use of such technique.

The number of variants which may be successfully studied in the one experiment frequently causes trouble. The natural desire is to incorporate as many aspects as possible. Where this results in imposing sub-treatments (which also may be further subdivided) upon major treatment groups, we have a frequent cause of inconclusive and wasted effort. This practice, common at most of our research stations, is justifiable only if the loss in degrees of freedom is compensated for by adequate replication as is readily the case in comparable plant work. Unfortunately, the number of animals which can be used in any one experiment, due to factors previously mentioned, seriously limits replication possibilities. In general it is the writer's opinion that the complex animal experiment is nearly always a case of 'more haste less speed' and that concentration on one major factor at a time is more profitable in the long run. A recent pig experiment reported from Rothamstead provides an excellent example of multifactorial design run riot. Two or more factor experiments within appropriate statistical designs are justifiable if one is concerned with inter-action effects. Some factors are complementary, others antagonistic in their inter-action. Study of their influence together as well as separately is often desirable. For example the writer is at present involved in complicated inter-action relationships between the influence of the sex glands and the shape of the growth curve upon the body (McMeekan and Wallace - unpublished.)

In respect to the number of variants, it should be unnecessary to point out that in all objective experimentation it is essential to eliminate the effect of all influences possible save those under study. Yet a large amount of meat investigation is carried out without the standardisation of one of the major factors productive of differences in body composition - that of final live or carcase weight. The relationship of growth changes to body structure insists upon this; all work on meat animals of recent years stresses the important influences of weight per se upon the characters we are interested in.

Finally there is the major question of the extent of treatment differences which should be applied in experimental work. For reasons which will be obvious from the foregoing general arguments the writer inclines to the use of extreme treatments whenever possible and particularly where such a technique does not conflict violently with practical considerations. Though this view is often challenged on practical grounds, it is surely more practical to employ methods which will yield conclusive results than to persist with methods that inevitably return a verdict of 'not proven'. The device markedly increases sensitivity in a type of research work beset with difficulties. Even though extreme treatments may be divorced somewhat from average field conditions it is more valuable to know that specific factors have effects upon the animal than to be doubtful because of one's inability to demonstrate the fact experimentally, due to defects in technique.

SUMMARY: In the execution of research in meat production it is suggested:-

- (1) That the survey method has its major function as a guide to planned objective experimentation.
- (2) That carcase measurements, the validity of which has been established on quantitative grounds, provide adequate criteria for survey work and for the evaluation of treatment effects in most experimental projects.
- (3) That the use of 'sample joints' and 'complete dissection' techniques for evaluating experimental results is essential to the more critical type of research.

- (4) That the difficulties associated with experimental material may be eased by the development of uniform strains of animals by inbreeding and by the use of suitable laboratory animals.
- (5) That modern principles of statistics in relation to experimental design must be employed in the planning of all objective experiments if maximum sensitivity and efficiency is required.
- (6) That the individual feeding technique is essential to critical work, group feeding having its place in larger scale field work.
- (7) That knowledge of population variance is a necessary guide to planning experiments in respect to both number of animals required and general design.
- (8) That the single factor design should be used when treatment differences are small and when it is not intended to study interaction effects: that complex experiments should be strenuously avoided except when treatment differences are large and replications adequate.
- (9) That the use of 'extremes' in treatment difference is a justifiable and valuable experimental device contributing markedly to sensitivity and significance.

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