protein value of approximately .97. I don't think that it is either necessary to dissect or analyse but merely to weigh, in so far as the general attributes, from a nutritive point of view of New Zealand fat lamb and mutton carcases are concerned. I know that the weight alone provides as effective an indication as anything. However, that does not obviate the necessity for having to know something about the weight of bone and weight of muscle and weight of fat tissues in a carcase, because after all we don't eat chemistry. We like a particular proportion of muscle to fat, so that along with any expression expression of value of a carcase or meat animal in terms of its chemical composition, must always go, in my opinion, some measure of its macroscopic and anatomical proportions.

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## THE INFLUENCE OF SEX UPON CARCASS QUALITY AND EFFICIENCY OF FOOD UTILISATION.

by

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Sex has long been recognised as a major factor influencing the form, structure, and behaviour of farm animals. It is a matter of common observation that males, females and castrates differ markedly in many characters. Obvious from casual inspection are the so-called secondary sex characters involving appearance of the head, neck and hind-quarters, differences in size, form and degree of fatness, and effects upon temperament and behaviour.

Many workers have recorded measurements of the effects of sex upon various characters of the pig, ox, sheep and fowl, and have demonstrated its modifying influence on the suitability of these species for meat purposes. Recognition of the importance attached to sex by the meat producer is reflected in the widespread adoption of the practice of castration of males intended for fattening. Females are less commonly deprived of their sex glands under modern conditions where most females fattened are disposed of either before or shortly after puberty so that the more difficult operation of spaying is not considered worthwhile. Spaying was commonly practised when animals were slaughtered at older ages and heavier weights. It is still employed to a limited extent with females no longer required for breeding.

The marked effects of sex are becoming more understandable with increasing knowledge of the endocrine basis of metabolic processes. The gonads are known to function as endocrine glands. Their removal may affect the animal directly by depriving it of the normal sex hormones or indirectly through interactions between this loss and the endrocrine system as a whole. Little information is available on the precise mechanism involved.

Though this general picture is widely appreciated, very few systematic data are available on sex effects. With the notable exception of the work of Murray (1) with pigs, comparisons have been limited in most cases to entire females and castrate males. Even Murray's data for entire and castrate animals of each sex cannot be considered entirely satisfactory since sex effects were confused with the influence of weight of animal. Further, his data were restricted to linear body measurements which have recognised limitations for precise work. McMeekan (2) provided more comprehensive information based upon complete anatomical dissection but also handled only the barrow and sow. He showed that barrows were characterised by less bone and muscle but more fat than sows. By using widely different growth curves in the production of pigs of common weight, he was able to reverse this situation. In the same way, normal sex differences were increased. The potency of the shape of the growth

curve as a modifying factor to sex is thus obvious, and provides the probable explanation of the many anomalous and conflicting reports from many sources. On this account, literature on the subject must be examined with critical reference to the growth rates of the animals studied, as well as to other factors likely to modify sex effects. Much of the data reported on all species have been derived from projects designed for other purposes, the information on sex being largely incidental. A typical example illustrative of the difficulties of interpretation of most observations is provided by Bengtsson (3) who found sows to be leaner than barrows but to have a slower growth rate. It is obviously not possible to decide whether the greater fat deposition of the barrow was due directly to sex or partly to rate of growth.

Conditions of war time food production have directed attention to questions of relative efficiency of food utilisation of farm animals, to a degree not apparent when peace time consumer preferences usually outweigh economic considerations. Here again, there is much incidental information suggesting sex to be a powerful modifying factor. Castration of the male is commonly accepted as conferring benefits in respect to economy of live and dead weight gain in cattle, sheep and pigs. Spaying of the female is likewise believed to have similar effects (8) (9) due to removal of the retarding influence upon growth of recurring estrus periods. Fundamentally, it has been established that castration lowers basal metabolism (4) (5) and it has been assumed in consequence that the castrate gives cheaper feed costs per unit gain. This theory is supported by the results of some workers (3) (6) (7) and contested by others (8) (9) (10). Dunlop (11) has shown that differences in economy of food utilisation of the fattening animal is tied largely to the relative rates of fat deposition. Since sex exerts a marked influence on fat metabolism the relative efficiencies of the four sexes might be expected to vary with the fat content of their daily gains as well as with the food required per unit of gain. No definite evidence on this important point has been reported.

In view of the foregoing, an investigation designed to elucidate the detailed pattern of differences in body structure due to sex and the effect of sex upon the efficiency of food utilisation was initiated and completed in 1940. War time publication difficulties have prevented a full report to date. It was hoped that the work would provide material of interest not only to the animal husbandryman but also to workers in more specialised fields.

Using the pig as an experimental animal, all four sexes have been studied under conditions designed to eliminate influences other than direct sex effects. Six sets of Tamworth pigs were involved. Each set consisted of four littermates and included an entire male, entire female, castrate male and castrate female. Spaying and castration were carried out at three weeks, and weaning at eight weeks. No difficulty was experienced in the operations and no setback to growth was recorded. All pigs were reared on the same ration and food consumption data were recorded. Growth rate was controlled under individual feeding conditions by control of intake, such that the four members of each set followed the same growth curve from birth to bacon weight of 210 lbs. The rate of growth of any one set was conditioned by the rate of growth of the slowest growing member under ad. lib. feeding. It will be noted that the design was strictly comparable to the randomised block layout widely used in field plot experimentation so the data obtained were readily subject to statistical treatment.

The technique of McMeekan (2) was followed in pre- and post-slaughter examination of conformation, structure, and chemical composition differences. His modification of sample joint dissection (leg plus loin) was employed with all sets with the exception of one where complete anatomical dissection was practised. It is obviously impossible in this short paper to report more than a very brief summary of the great mass of data obtained.

EFFECTS ON BODY PROPORTIONS:

The general trend of effects upon body form suggested that the gonads influence the various parts of the body differentially and in accordance with the order of development of these parts. Thus late developing parts were encouraged and early developing parts retared by removal of the sex glands. This situation is illustrated by the relative weights of leg and loin joints of the four sexes. (Table I). The loin joint (late developing) is heavier but the leg joint (early developing) lighter in the castrates. The relative effect of castration is also greater on loin than on leg.

TABLE I.

RELATIVE WEIGHTS OF LEG & LOIN

| Sex | Weight of Leg. | Weight of Loin | Ratio Leg/Loin |
|---|---|---|---|
| Entire Male | 100 | 100 | 0.94 |
| Castrate Male | 95 | 114 | 0.78 |
| Entire Female | 102 | 113 | 0.84 |
| Castrate Female | 96 | 117 | 0.77 |

EFFECTS ON ORGANS:

In respect to organs and offals, the weights of blood, skin, hair and thoracic organs were greater in entire males than females, and greater in each of these sexes than in castrates. This situation was reversed in respect to abdominal organs. These and other differential effects upon organs can be explained in terms of the relative order of development of these parts. Few organs behaved in a manner not consistent with this theory. Special mention must be made of the kidneys which were considerably heavier in entire males than in the other three sexes. This result was unexpected in view of the generally accepted theory that kidney weight is largely dependent upon the quantitative level of protein intake. This was actually least in the case of the entire males. (See Table 6). No satisfactory explanation for this situation was found.

TABLE 2.

RELATIVE WEIGHTS OF ORGANS

| Sex | Total Organs. | Abdominal Organs. | Kidneys | Liver | Kidney Fat. | Blood |
|---|---|---|---|---|---|---|
| Entire Male | 100 | 100 | 100 | 100 | 100 | 100 |
| Castrate Male | 103 | 108 | 82 | 105 | 139 | 91 |
| Entire Female | 102 | 107 | 82 | 116 | 117 | 94 |
| Castrate Female | 107 | 115 | 91 | 117 | 139 | 91 |

Of interest also from a practial viewpoint was the consistent greater weight of offals in females and castrates of both sexes than in the entire male. This naturally influences dressing percentage in favour of the latter sex.

EFFECT OF COMPOSITION:

As determined by dissection of leg and loin and supported by complete dissection of one set, very large and differential effects were produced upon the weight of bone, muscle and fat. (Table 3) Entire animals had more bone and muscle than castrates, and males more than females. On the other hand, castrates yielded a greater weight of fat than entire animals and females more than males.

TABLE 3:

RELATIVE WEIGHTS OF MAJOR TISSUE

| Sex | Bone | Muscle | Fat. | Skin |
|---|---|---|---|---|
| Entire Male | 100 | 100 | 100 | 100 |
| Castrate Male | 91 | 88 | 146 | 77 |
| Entire Female | 96 | 97 | 137 | 79 |
| Castrate Female | 87 | 89 | 151 | 78 |

As in body proportions, castration affected most the late developing tissue (fat) and less the early developing tissues. (bone and muscle). Castration of male animals resulted in more extensive changes in carcass composition than castration of females. (Table 4).

TABLE 4:

RELATIVE EFFECTS ON MALE AND FEMALE.

| TISSUE | Castrate Female/ Entire Female | Castrate Male/ Entire Male |
|---|---|---|
| Bone | 91.1 | 90.6 |
| Muscle | 91.7 | 88.4 |
| Fat | 110.4 | 145.6 |

Bone and muscle were retarded more and fat stimulated more in the castrate male. It was also observed that in all major characters measured, male and female castrates tended to resemble each other very closely, but large differences existed between male and female entire animals especially in fat development. Entire females carried 35 per cent more fat than entire males. It would appear that in some way the gonads retard fat development and favour bone and muscle and that the testes do this more effectively than the ovaries. When each is absent, bone, muscle and fat development proceed in a very similar way irrespective of whether the animal is genotypically male or female.

EFFECT ON BONE DEVELOPMENT:

In view of the importance of bone size and shape to meat production, and to any aspect of animal production involving conformation and composition, the relative effects of sex on bone growth are of some interest. Comparison of the weights of individual bones of the loin and leg regions clearly indicated the depressing effect of the sex glands on the relative growth of late developing parts. As in the case of the three major tissues, these comparisons support the suggestion that the gonads of the male are more effective in this connection than those of the female.

Castration resulted not only in a reduction in the weight of the individual bones but also in changes in the shape. (fig. 3.) Growth in both length and thickness was retarded by castration with a relatively greater effect upon the latter. (Table 5).

TABLE 5:

RELATIVE EFFECT ON BONE GROWTH

| Sex | Weight Femur. | Weight Pelvis | Length Femur. | Weight/ Length. |
|---|---|---|---|---|
| Entire Male | 100 | 100 | 100 | 100 |
| Castrate Male | 90 | 87 | 96 | 93 |
| Entire Female | 96 | 93 | 100 | 96 |
| Castrate Female | 87 | 84 | 95 | 91 |

The castrate tended to have lighter and finer bones than the entire, with females resembling the castrate more than the male. (Fig. 1.)

EFFECT ON EFFICIENCY OF FOOD UTILISATION:

Reliable food consumption records on an individual feeding basis were available for all animals for approximately 75 lbs. live weight to 210 lb.s live weight, so that data on food utilisation cover only this range. Efficiency of food utilisation may be measured either in terms of the amount of food consumed per unit increase in weight, or in terms of the amount of net energy consumed in proportion to the amount of net energy stored by the animal. The first is the usual measure adopted by the animal husbandman in assessing efficiency and is of direct practical use in that it provides a ready measure of the relative cheapness of gains of the animal. The second is a more accurate measure of efficiency of the animal as a producer of human food since it measures its ability to convert raw materials into usable human food.

The first method is employed in Table 6, which shows the amount of food in terms of pounds of Starch Equivalent consumed per pound of dressed carcase gain produced.

TABLE 6:

FOOD CONSUMPTION PER POUND OF GAIN.

(Dressed carcass basis)

| Sex | S.E. lbs. | Relative Efficiency Per Cent. |
|---|---|---|
| Entire Male | 3.26 | 100 |
| Castrate Male | 3.94 | 79 |
| Entire Female | 4.07 | 75 |
| Castrate Female | 4.14 | 73 |

The entire male was consistently outstanding in making the most economical gains. The other three sexes differed only slightly though the castrate female proved the least efficient. The superiority of the entire male gave this sex an advantage of more than 20 per cent in the amount of food required per pound of dressed gain carcase produced.

On the alternative basis - that of energy consumed to energy stored - this position was reversed. (Table 7.) The data have been derived from the calorific value of the digestible nutrients fed and the calorific value of the muscle and fat depots laid down during the fattening period. This latter has been calculated from estimated initial and final carcase composition data based on dissection results, and chemical analysis of the muscle and fat tissues. The energy content of bone growth has not been taken into account.

TABLE 7:

RELATIVE EFFICIENCY OF FOOD UTILISATION.

(Ratio energy consumed to energy stored)

| Sex | Cal.fed/ Cal.stored | Efficiency of Conversion Percent | Relative Efficiency Percent |
|---|---|---|---|
| Entire Male | 2.69 | 37.1 | 100 |
| Castrate Male | 1.92 | 52.2 | 129 |
| Entire Female | 2.15 | 46.6 | 120 |
| Castrate Female | 1.93 | 51.8 | 128 |

Efficiency varied directly with the differing energy content of the gains of the different sexes. Thus the entire male, storing the least fat, was by far the least efficient. The castrates, storing the most fat were the most efficient. The entire female, storing an intermediate amount of fat was intermediate in efficiency. This reversal of effect was so striking as to shift the entire males from a superiority of 20 per cent on a food consumption per unit gain basis, to an inferiority of from 20 to 30 per cent on an energy fed/ energy stored basis.

Of almost equal interest, is the relative efficiencies of the sexes in respect to storage of protein. This has been calculated on a basis of grams of protein stored per Therm of digestible energy consumed. (Table 8.) The diet provided a large excess of protein so that there is no point in calculating protein efficiency on a basis of protein fed to protein stored.

TABLE 8:

RELATIVE EFFICIENCY OF PROTEIN STORAGE.

| Sex | Protein Stored Per Therm grams | Relative Efficiency |
|---|---|---|
| Entire Males | 12.13 | 100 |
| Castrate Males | 7.95 | 66 |
| Entire Females | 9.24 | 76 |
| Castrate Females | 7.69 | 63 |

Here also, efficiency varied directly with the composition of the gains. With the greatest muscle deveopment and therefore storing the most protein, the entire male was 25 per cent more efficient than the entire female and 35 per cent more efficient than the castrates.

DISCUSSION:

Quite apart from the general scientific interest of these findings, several points arise of distinct interest to pig production.

It is clear for example, that castration of either sex adversely affects the suitability of the carcass for modern bacon trade requirements. The castrates tend to carry excessive fat, reduced muscle, and have a higher dressing loss. In addition they make less economic gains in relation to food consumed. Since payment to the producer is per pound of carcase with a differential in favour of quality, the castrate brings a lower cash return. The only apparent advantage of the castrate is the small wastage in bone, but since this - as in all meat animals - is accompanied by a corresponding reduction in muscle, it is really a disadvantage.

On the other hand the superiority of the entire male is outstanding. With a much smaller fat cover, it provides a leaner, better muscled carcass, with the smallest loss in dressing. Characterised by a low food consumption per unit gain, it is by far the most economical of the four sexes from a feeding point of view. Thus, combined with its superior carcass quality, it yieldsa higher cash return for feed expended. It is important to note that no evidence of any adverse effect upon the flavour or tenderness of the meat or resulting cured bacon was observed in the entire males. Although reared from birth to bacon weight in constant association with their entire sisters which had several estrus periods during the fattening term, no mating occurred. Thus management difficulties resulting from non-castration did not occur. The question thus arises as to whether adherence to the practice of castration of boar pigs intended for fattening is necessarily sound under present day conditions where pigs for both pork and bacon are slaughtered at such an early age and before sexual activity has been reached.

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DISCUSSION

Professor W. Riddet: Mr. Wallace, through Dr. McMeekan, has explained that age of castration could be materially delayed to advantage. It would be interesting to know from those closely associated with meat inspection whether, in their opinion, it would be sage to delay castration. Alternatively, might there not be other methods of approach, as instanced here with respect to the possibility of using sex hormones for administering to de-sexed pigs with a view to aiding rate of growth. I doubt whether it would be of much practical value in making better use of the calorific value of the food because it is, after all, conversion into food which is not wanted from a consumer's point of view.

Mr. Ballinger: Are these relative efficiencies present throughout the entire period or are they only apparent or real during the latter stages, that is, is it so in the light baconer as it is in the baconer killed in the 210 lbs. live weight?

Reply: From my association with the work at the time and from what records I have seen I would say they apply over the whole period. The only reason why Wallace has concentrated his efficiency data over the 75 lbs.- 210 lbs. liveweight range is because it was during that period only that he was able to effectively employ individual feeding and therefore to obtain detailed individual intake figures, which of course are essential for any adequate statistical analysis of this work.

Mr. N. Clare: In various studies by students, and in particular in a lot of work done overseas in haemoglobin formation and destruction, the question of measurement of blood volume has proved very tricky. Bleeding out does not give good enough estimates and that is incidental to the fact that it is no good if you want the animal alive. I was interested in what technique was used in this work for estimating the blood.

Reply: The pig was slaughtered by having its jugular cut in a suspended position and the blood was collected by normal straight out drainage. I quite appreciate the difficulties there in getting complete separation of blood from the carcase, but I would just point out that the differences noted, which are of the order of about 10%, were thoroughly consistent. There was no overlapping insofar as the entire males were concerned; they had in every case (in 6 sets of pigs) 10% more blood. The differences were significant.

Dr I.L. Campbell: You raised the point about the possibility of making trials on the use in practice of hormones on the castrate male or female. In our present state of knowledge that would be possible only in an experimental way. As far as the female is concerned we have cheap female sex hormones in Hexestrol, Diethylstilbestrol, or Stilbestrol. These have the advantage that they are potent when fed though not quite as potent as when they are injected. When we turn to the male sex hormone, we have available natural products in the various androgenic hormones, but they are at present rather costly to be used in any other way but experimentally. The most potent one available is testosterone. This is not very potent when given by mouth. We do have a less potent androgen, methyl-testosterone, which is potent by mouth, but that again is very costly. Since Mr. Wallace's work has been written up there has been published by Gardner and his assistants at Yale some work on the effect of estrogens on bone. It is interesting to note that in the pelvic region of estrogen-treated animals Gardner found bone re-absorption, in contrast to the effect found in the long bones where bone formation, particularly endosteal bone formation, was promoted. What part does Mr. Wallace think the effect of the presence or absence of sex hormones played on the basal metabolism or the maintenance requirements of these animals, and therefore on their efficiency of gain? In experimental animals it is recognised that the sex hormones have an effect on their activity, that is, on the amount of activity. With these castrate animals was there such an effect in that their maintenance requirements were low, and therefore the efficiency data thus affected?

Reply: Unfortunately, Mr. Wallace has no data at all on the maintenance metabolism side. I think, however, that Dr. Campbell has put his finger on what is perhaps one of the most interesting fundamental aspects of the work, in that theoretically castration lowers basa metabolism, therefore should lower maintenance requirements, and therefore make the castrate more efficient in terms of its weight increase in terms of food intake. That has not happened and that was one of the points which interested Mr. Wallace especially. He was also hoping to follow up the point raised by the Chairman and yourself re the treatment of castrated animals with hormones, but of course the war has put that out of gear. On that particular point I would like to express just one opinion, and that is that, while that is obviously quite a promising line of research, I think any use of hormones in this connection would need very definitely