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MEAT STUDIES IN THE ROMNEY EWE
(IN TWO PARTS)

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PART 1

OBESITY IN THE EWE

CHAPTER I

INTRODUCTION

> "There is a steadily growing aversion to fat on the part of consumers. This, although partly a reaction to the over-fat meat which was issued during the rationing period, is also stimulated by the high price of meat, the demand for very small joints, the elimination of heavy manual work and medical pronouncements about the dangers of obesity." (Pomeroy, 1956).

It has been recently emphasised that the production of light weight sheep is becoming an increasingly important selling point in New Zealand's main market, the United Kingdom, (Anon, 1956). Evidence is accumulating which suggests that the consuming public is becoming increasingly unwilling to purchase overfat meat. Recent articles have stressed that the overfat ewe is a serious problem in New Zealand, (Smith-Pilling and Barton, 1954; Merritt, 1954). However, this cannot be considered a new problem, as overfatness was one of the main difficulties hindering the disposal of New Zealand mutton carcasses in the United Kingdom, soon after the founding of the frozen meat industry, (Pharazyn, 1884). Because tallow and the skins were the main marketable products of the sheep prior to the development of this industry, the production of animals carrying surplus fat was not surprising at that time. It is more surprising to find that no research has been carried out on this problem in the subsequent 72 years.

At the end of the lambing period on New Zealand sheep farms, the ewes are likely to encounter situations of feed surplus in seasons of good pasture growth. The effects of this surplus are later accentuated by the removal of drafts of fat lambs. Under such circumstances, the ewe has optimum conditions for its inherent tendency to accumulate large quantities of fat.

The ten-year average for ewe carcasses, -- 1946-47 to 1955-56 -- was 56.8 lb, (1956 New Zealand Meat Producers Board Annual Report) and the evidence given by

Smith-Pilling and Barton (1954) suggests that such carcasses have on average, 20 lb. of fatty tissue.

Because of the increasing consumer resistance to overfat meat, it is not surprising to note in the 1956 ewe schedule prices that the farmer makes a lower gross return from the heavier ewe carcasses. This indicates that emphasis should be placed on producing a larger number of lighter sheep, instead of the heavier animals as at present. Furthermore, those ewe carcasses heavier than 72 lb. as well as those under 72 lb. which are classed as overfat, are graded as manufacturing meat; this represents a loss of export income to our economy.

Apart from the direct loss stated above, there is an indirect one effecting both the farmer and the nation. Thus seasonal fluctuations in the state of fatness of ewes have been implicated in sleepy sickness, eversion of the vagina, infertility; and it is a well known farmers' observation that heavier ewes are more prone to become cast.

From the point of view of human nutrition also, the evidence suggests that overfat meat may constitute a health hazzard. The theory has recently been advanced by Bronte-Stewart et al. (1956), that the eating of fats derived from land animals may predispose people to coronary disease. Keys (1956) considers degenerative heart diseases to be caused by the general high level of fat in the diet of the effected people. Both of these theories suggest the desirability of leaner meat.

As a research attack on the overfat ewe problem, the ewe pre-slaughter was used as the starting point. In terms of efficient farming on the other hand, it may be argued that the problem can be overcome by increasing the stock carrying capacity and thereby preventing obesity. In practice this approach is unlikely to be widely followed because of managemental difficulties and the risks involved.

To be of practical use, any method chosen to reduce the surplus fat from the animal, should achieve results quickly, i.e. between the time that the lambs are

weaned and the ewes are sold to the meat works. The first method selected was the use of thyroxine implants. The literature suggested that thyroxine can remove body fat rapidly, and implantation would appear to have possible practical application under farm conditions. Secondly, a short term low plane of nutrition is a farming possibility. This treatment can also provide information which may be of use in relation to the shutting up of sheep, to prevent the development of facial eczema, and during which a low plane of nutrition may be imposed.

In order to evaluate reliably the results of the experimental treatments, body weight was interpreted in terms of its components.

Finally this experiment assists in the search for techniques that may be used in studying the manner in which animals gain and lose weight. In view of the importance of the proportion of fatty tissue in meat, in terms of both consumer preference and of animal and of public health, the research worker must attempt to find methods to control the gain and loss of this tissue. If New Zealand is to maintain its position as the world's largest exporter of meat, then the farmer must increasingly attempt to control the factors influencing carcass acceptability and productive efficiency.

CHAPTER II

REVIEW OF LITERATURE

(A) THYROXINE EFFECTS ON BODY WEIGHT AND ITS COMPONENTS

The biologically active iodine compounds of the thyroid gland appear to be l-thyroxine and l-triiodothyronine (Roche and Michel, 1955). The iodination of proteins under suitable conditions produces equal quantities of l-thyroxine and the inactive form, d-thyroxine.

Although in low doses, thyroxine, as such or as iodinated casein has been used as a growth stimulant, it is well known that hyperthyroid animals receiving thyroxine at levels above physiological normality lose body weight, (Blaxter et al., 1949). Drill and Shaffer (1942) report a 10.5 kg. dog which lost 2 kg. body weight in 30 days when fed desiccated thyroid tissue. In cows, weight losses of up to 150 lb. (being 10-15% of the original body weight) have been recorded by Seath et al. (1945). Seath et al. (1944), and other authors (Blaxter, 1945; Owen, 1948a) report that weight losses following the administration of iodinated proteins, are common in cows.

In sheep also, weight losses under thyroxine treatment are common. (Hart, 1955; Jordan, 1954; Warwick et al., 1948), and in fact Turner and Reineke, (1946) used weight loss in this species as an assay technique for the thyroxine potency of thyroprotein. Blaxter (1948), working with wethers recorded losses of up to 28% of the original body weight in 24 days. Two of his wethers died and great variability of response to treatment was noted.

It has been shown that the effects of thyroxine administration on body weight can be modified by diet. The weight loss in hyperthyroid cows can be partly or wholly prevented by giving extra food, (Blaxter et al., 1949). It was thought by Reed et al. (1932), that the failure of heavy rats fed thyroxine to decline in body weight could be explained by their greatly increased food consumption. Kennelly et al. (1953) showed that in rats, desiccated thyroid tissue administered with a

diet high in fat, had little effect on weight gain. On the other hand, the average weight gain was significantly less in both male and female rats on a diet low in fat.

In ruminants, it appears that one of the ways that thyroxine reduces liveweight may be by lowering the weight of gastrointestinal contents. This could be caused by an increased rate of peristalsis, or in more severe cases of hyperthyroidism, by lowered food intake or by starvation.

Frens (1949) found that liveweight gains in cows fed methyl-thiouracil, which is an antithyroid compound, could be largely attributed to a 50-70% increase in weight of the ruminal contents. He presumed that hypothyroidism caused a lowering of the tone of the nervous mechanism governing the emptying of the rumen. It might therefore be expected that liveweight losses due to hyperthyroidism in ruminants, could be caused by a decrease in the quantity of gastrointestinal contents, resulting from an increase in the rate of peristalsis, or an increase in the tone of the nervous mechanism governing the emptying of the rumen. In cattle treated with thyroprotein, Blaxter et al. (1949) in England reported that 7.7% showed signs of scouring or digestive upset as compared with 1.7% of the controls; the difference being highly significant statistically. In hyperthyroid sheep a fixed ration declined in digestibility associated with an increased water excretion by the bowel (Blaxter, 1948), and it was concluded that the passage of food was probably speeded up and resorption of water was impaired. It was presumed that some of the loss of liveweight by sheep in this investigation was due to reduced gastrointestinal contents.

Balch et al. (1952) checked the rate of passage of food through the digestive tract of four hyperthyroid cows using a strained hay t echnique. After a control period the cows were made hyperthyroid by oral administration of l-thyroxine. The treatment caused an average decrease of from 16.5% to 15.5% in the dry matter of the faeces of each cow. This decrease was likely to be linked to the raised water intake during the period of thyroxine administration and the resultant fall in dry matter

content of total intake. Thyroxine treatment caused no consistent change in the rate of passage of food through the digestive tract. There was evidence, however, that in three of the four cows, food passed slightly more rapidly through the rumeno-reticulum, but the rate of passage of food through the remainder of the alimentary tract was unchanged.

In extreme hyperthyroidism the self-imposed starvation reported by Blaxter (1948), in wethers, would lower the weight of gastrointestinal contents. However, the evidence of Balch et al. (1952) does not support the hypothesis advanced that thyroxine administration would cause a weight loss of gastrointestinal contents of ruminants by increasing the motility of the digestive tract. Ivy (1930), on the other hand, presents evidence to suggest that hyperthyroidism caused increased rate of stomach emptying in non ruminants.

Blaxter (1948, 1948a) produced evidence to show that the weight loss in his wethers has factorised between loss of muscle, alimentary fill and bone, and the large residual was assumed to be fat. He found, upon postmortem examination of the bodies of the slaughtered animals, and those that had died of treatment effects, an almost complete absence of subcutaneous fat and fat in the abdominal cavity of the thyroxine treated sheep as compared to the controls. In these latter sheep, "the most striking difference was the large quantity of fat present in the abdominal cavity and beneath the skin."

In rats, Reed et al. (1932) found that the proportionate distribution of fat in the depots of two groups fed thyroxine was similar to that in the untreated control animals. The percentage content of depot fat in the entire body of rats fed thyroxine was however less than half of that found for control animals. Kennelly et al. (1953), fed desiccated thyroid tissue to young and old rats on high and low fat diets, fed an ad libitum diet. They found little difference in fat composition of the carcasses between thyroxine treated rats on a high fat diet and the controls.

However, in thyroxine treated young rats there was significantly less total lipid (at the 1% level) as compared with control young rats. This was shown to be in the neutral fat fraction as compared with the essential lipids. In old rat carcasses also, this same result was found, but only at the 5% level of significance. The evidence thus suggests that thyroxine treatment may be more severe on growing than on mature animals.

Using an isotope technique in a study of hypothyroidism and hyperthyroidism, Karp and Stetten (1949), replaced a portion of the body water of immature female rats by deuterium-oxide and observed the rates at which the stably bound deuterium appeared in the tissue fatty acids. The rats fed desiccated thyroid tissue contained almost 25% less depot fat per 100g. body weight than did the controls. At the end of the experiment, the carcass weights averaged 114g, for the control animals, 96g. for the thiouracil treated group, and 83g. for the hyperthyroid animals. In every case, the thyroid fed animals gave fat samples richer in deuterium than did the other two groups. It was estimated that in the normal, hypo- and hyperthyroid animals respectively, 1.2, 1.1 and 1.0g. of depot fatty acids were replaced daily by newly synthesised fatty acids.

The more rapid rise in deuterium concentration of the carcasses of the thyroid fed rats was ascribed to the higher deuterium uptake expressed as a percentage of that present in the body water, and to the paucity of depot fat. The diminuition in the quantity of depot fat which followed the administration of the thyroid tissue, in spite of a virtually normal rate of deposition of newly synthesised fatty acids, was considered to be attributed to accelerated degradation of body fat. This is in contrast to the mechanism of diminuition in the quantity of fat observed in diabetes, undernutrition, and thiamine deficiency. In these cases a striking reduction in the rate of lipogenesis is observed.

There is some evidence that hyperthyroidism increases nitrogen metabolism which

is suggestive of protein katabolism. In sheep, Blaxter (1948) reports that treated animals lost body nitrogen when iodinated casein was given, the loss being proportional to the dosage. Calculations indicated increases in endogenous katabolism of up to 120%, and also increases in deamination. There was an increased excretion of urea and ammonia during hyperthyroidism, the latter being associated with a decrease in plasma carbon-dioxide combining capacity, which is indicative of slight acidosis. Owen (1948a) reports that in hyperthyroid cows, nitrogen balances became negative, while in a control cow, nitrogen balances remained positive. After hormone treatment ceased, the balances of the experimental animals became markedly positive. These results were repeated in a second experiment. It was found that the excessive katabolism could be inhibited by increasing the intake of food.

Blaxter (1948) found in hyperthyroid sheep that the calcium balances became negative. The extent of depletion of body minerals is indicated by the fact that one wether lost 10% of its body calcium in 24 days. There was a comparable large depression in the phosphorous balance.

Owen (1948) concluded that in thyroxine treated cows, the apparent digestibility of dietry calcium was very low and this together with negative calcium balances he considered might lead to a depletion of the calcium reserves. This could be dangerously excessive unless dietry measures were taken to make good the loss. The phosphorous balances, obtained for two cows only, were positive throughout the whole experiment, the thyroxine actually tending to increase the amount of phosphorous retained. As two of Blaxter's wethers died, it is probable that his sheep were more severely hyperthyroid than Owen's cows, which could help to explain the different results from the two experiments.

Brody (1945, p.174) reports that another effect of feeding thyroid tissue is hypertrophy of the heart, liver, spleen and adrenals. Cameron and Carmichael (1921) present evidence that treatment of rats with thyroid tissue lowers the weight of the

thyroid gland in the treated animal.

The evidence presented suggests that thyroxine should be a useful experimental tool for causing a body weight reduction in ruminants. It would seem that this weight loss may include losses of gastrointestinal fill, and should include losses of fat, protein and minerals with fat being a considerable portion of the total weight loss.

(B) EFFECTS OF STARVATION AND SEMISTARVATION ON BODY WEIGHT AND COMPOSITION

A review on starvation with particular reference to the human species is given by Keys et al. (1950).

The total loss of body weight in hibernating animals was estimated by Morgulis (1923) not to exceed as a rule 20-25% of the initial weight. It is of interest that after hibernation, the weight of depot fat in a marmot had decreased by 99.3% of the original value. Losses of body weight obtained under natural and experimental conditions will vary within wide limits from species to species, and in ruminants losses of gastrointestinal fill may be of importance.

Preobrajensky and Baranova (1932) reported on a dog that died after losing 65% of its initial body weight in a 93-day fast. Pomeroy (1941) quoted the weight of a pig that during a 135-day submaintenance period had lost 67% of its initial liveweight. However, recalculation of his data indicated that the weight loss was 45.2% of the initial liveweight. In the sheep, Robinson (1948) reported a weight loss in a ewe of 53% in 208 days, and White et al. (1956) reported the loss of one pound liveweight per day in wethers during 10 days starvation, following a period of submaintenance.

Franklin (1952) presents the results of an experiment for estimating the maintenance rations of Merino wethers under drought feeding conditions. The initial average liveweight of the wethers was 94 lb. During the latter part of the experiment the sheep were fed at weekly intervals. Over a 344-day period, the liveweight of the surviving 127 wethers, dropped on the average by 22-27 lb. for different groups, which loss included a mean of slightly over 7 lb. of wool. The death rate

in the weekly fed wethers was 11.8% with over 72% of these deaths occurring in sheep which had lost 40% or more of their initial body weight.

(1) Body fat

The large extent to which the total body fat may decrease in undernutrition has been repeatedly demonstrated in various animals. Pfeiffer (1887) presented data for a rabbit which starved for 13 days. The fat content of the subcutaneous, intermuscular and abdominal adipose tissues decreased by 66, 51 and 75% respectively. Dibble (1932) demonstrated that in rats fasting for over 60 hr., a loss of 23% body weight and 55% body fat occurred. Meyer et al. (1956) showed that feed restriction on growing rats had the greatest effects on percentage fat in their carcasses. Widdowson and McCance (1956) described the effects of chronic undernutrition and total starvation on growing and adult rats. Six days starvation reduced the fat composition of the adult male and female rat bodies by 19% and 37% respectively. Undernourished adult male and female rat bodies which had lost the same body weight as the starved animals (15% body weight loss) had the fat percentages reduced by 31 and 40 respectively.

Pomeroy (1941)reports that, in pigs, the effects of submaintenance on the fat of the carcass is much more severe than on muscle or bone. Subcutaneous fat, which is later developing than intermuscular fat, is penalised to a greater extent. On the other hand the abdominal fats, which are earlier developing than subcutaneous fat, are not so adversely effected. In addition the subcutaneous and intermuscular fat of the late developing joints, suffer greater losses in weight than the corresponding fats of the earlier developing joints.

In an experiment with sheep on super- and submaintenance diets, Robinson (1948) presented evidence to show that the magnitude of the effects on the three main carcass tissues were in the reverse order to that of their development. Fat showed a change, commencing slowly and then proceeding rapidly in the supermaintenance series, but decreasing rapidly at first, and then more slowly in the submaintenance series. The decrease of mesenteric, omental and perirenal fat in the submaintenance animals

proved very erratic and no conclusion could be drawn.

(2) Muscular tissue

Keys et al. (1950, p.102) differentiate between obesity reduction, where fatty tissue is the primary and frequently the only component of the body being used up as fuel, and semistarvation in which muscular and glandular tissues as well are drawn on as a source of calories. They report (p.184) that marked atrophy of the skeletal musculature is a prominent characteristic of severe undernutrition and acute starvation, in both man and other animals. In general the proportional loss of skeletal muscular mass is close to that for the body as a whole.

Jackson (1915) found an average loss of 31% of the muscular tissue in albino rats acutely starved until there was a body weight loss of 33%; in chronic undernutrition with an average weight loss of 36%, the musculature was estimated to have decreased in weight by 41%.

Pomeroy (1941) with pigs, and Robinson (1948) with sheep, both species on submaintenance rations, showed that proportionately less muscular tissue is lost than fatty tissue.

(3) Bony tissue

Keys et al. (1950, p.218) present evidence to suggest that the bony skeleton loses less weight relatively, during starvation, than does the body as a whole, or than do the blood, fat, muscle and internal organs. Whether the same conclusion holds for the conditions in semistarvation is not known.

Sedlmair's (1899) two cats which lost 51% and 55% of their body weight, lost only 3.7% and 3.8% of the mineral matter of the bony skeleton. It seems that the water, fat and organic components of the skeleton are reduced more than the minerals during starvation.

Pomeroy (1941) with his pig data, showed that on submaintenance rations there remained a tendency for bone to continue to grow, and only when the submaintenance regime was prolonged did any apparent loss in weight occur. Robinson (1948) was

unable to demonstrate any effects on weight of bone in his submaintenance ewes.

(4) Organ weights

(a) Liver

Keys et al. (1950, p.191) report that in almost all cases, starvation or chronic undernutrition produces a marked loss in weight of the liver, though the high degree of normal variability in this organ makes the interpretation of individual data difficult. The relative loss of liver weight seems to exceed that of the body as a whole so that liver weight is subnormal both in absolute and in relative terms. It seems certain that the weight loss is not a mere hydration change. It is probably related to both active metabolic and storage functions of the liver.

In his series of pigs, Pomeroy (1941) presents results showing a loss of 51.6% of the control liver weight (based on one liver during the first stages of submaintenance), and a slight reduction thereafter, taking total loss to 55% of the control value. Robinson (1948) with his ewes on submaintenance noted that there was an initial rapid fall of liver weight and then a more gradual decrease to a minimal value of 26% of the liver weight of the control ewe.

(b) Kidneys

Keys et al. (1950, p.193) report that kidneys undergo atrophy in both acute and chronic starvation, but the degree of weight loss is ordinarily somewhat less than that of the body as a whole.

Pomeroy (1941) concluded that there was a loss of weight in the kidneys of his submaintenance pigs of from 20-30% of the control value although there seemed to be considerable variability. Robinson (1948) reported a trend similar to that observed for the livers of his submaintenance ewes with a value of 42% of the control kidneys being reached.

(c) Spleen

Keys et al. (1950, p.193) report that the spleen normally shows great variability in weight among individuals, and in general during starvation the spleen loses

proportionately more weight than the body. Pomeroy's (1941) data on submaintenance pigs support this observation. On the other hand Robinson's (1948) data showed that the weight values of this organ from submaintenance ewes remained at relatively constant values throughout the experimental period.

(d) Heart

In their review, Keys et al. (1950, p.198) noted that with few exceptions, a comparison of starved animals with controls of the same species, indicated that the proportional loss of heart weight in starvation averages something like 70-90% of the body weight loss; there are a few reports that heart weight loss was relatively greater than that of the body as a whole. Pomeroy (1941) reports from data on pigs on submaintenance that the heart weight dropped rapidly to 73.5% of the control value during the first 23 days and thereafter slowly to 69.9% of the control value in 135 days. Robinson's (1948) data on submaintenance ewes showed a fairly stea dy loss of weight throughout the treatment period.

(e) Stomaches and intestines

The effects of undernutrition on the gastrointestinal tract is not as well documented as for other organs. However Keys et al. (1950, p.186) report that smoothe muscles respond to starvation much as do the striated muscles. Jackson (1915) quotes from his work with white rats, weight losses of the gastrointestinal tract of 57% in the starved animals as compared with the well fed controls. Pomeroy (1941) obtained evidence that there was a loss of weight of the stomach and intestines in pigs on a submaintenance diet. In the case of the small intestines this weight loss seemed to be composed of both a decrease in length and a thinning of the intestinal wall. Robinson (1948) showed a tendency of these organs to lose weight in submaintenance ewes. This was most pronounced in the case of the small intestine which initially appeared to lose weight rapidly and thereafter maintained a steady rate of loss.

From the foregoing review, it appears that a regime of undernutrition should

result in a loss of body weight. Of particular interest from the point of view of the present experiment, is the indication that, of the body components, fat seems to be the first tissue removed and at a proportionately greater rate than any other component of body weight.

(C) BODY COMPOSITION

(1) Body weight

In attempting to characterize the physical or nutritional status of an animal, the gross body weight is widely used as the first criterion. There are well known gradients of animal growth with fat being the last major tissue laid down. However, due to the genetically different sizes and proportionate composition of animals, body weight, even when differences in size of skeleton are considered, is a poor measure of fatness, (Keys and Brožek, 1953). The fact that the constituents of body weight, such as fat and water, may vary widely in their percentage contribution to the total, constitutes the fundamental limitation to the interpretation of body weight. In ruminants, the degree of fill can add to the variability of liveweight and so lower the value of body weight for predicting body composition.

(2) Prediction of body fatness from subcutaneous fat

The use of skinfold measurement to estimate fatness has been validated in man, (Keys and Brožek, 1953). There are, however, difficulties in applying this method to sheep owing to the thickness of the subcutaneous fat in the fatter animals, and the fact that the fat does not lift up with the skin (personal observation) in this species as it does in the human. This difficulty has been overcome by the use of a narrow metal ruler, (Hazel and Kline, 1952), and by the use of the "lean meter" of Andrews and Whaley (1954), both methods being discussed by Wilder (1955). Results from both methods are closely related to thickness of subcutaneous fat.

(3) Chemical approach

The concept of water forming a relatively constant proportion of the fat free

body of mature animals has become widely accepted. By the method of degree of dilution of antipyrine, many workers, (Kraybill et al.,1951; Kraybill et al.,1953; Hix et al.,1953; Hix et al.,1956; Breidenstein et al.,1955; Wellington et al.,1956), have used this concept as a basis to estimate the fat content of the body of meat animals. This fat content indicates the fat content of the carcass. However, before accepting this technique it would seem that the underlying assumptions should be carefully checked.

Murray (1922) and Moulton (1923) concluded that the fat free mature animal body mass comprising fat, water, protein and ash is relatively constant in composition. With at least the older animals, these workers would seem to have looked at the empty body, i.e. the eviscerated body.

Pace and Rathbun (1945) suggested a constant value in guinea pigs of 72.4% water (S.D.=2.11%), in the fat free eviscerated body. On averaging the data from other workers on many species, they suggest a value of 73.2% water in the fat free animal body as a biological constant, (range from 69.9% for dogs to 76.3% for rabbits). This work has been criticised by Keys and Brožek (1953) on the grounds that if the water concentration of the total body is a reliable measure of total fat free mass, it should be independent of the level of fatness. On the data of Pace and Rathbun (1945), the latter workers were able to calculate correlation coefficients between total body fat and % water on a fat free basis of $r=+0.45$ for males and $r=+0.31$ for females, (significant in both cases), Keys and Brožek interpret this as indicating that the body does not gain or lose fat as an entity.

Babineau and Pagé (1955) showed water to be a constant in the fat free bodies of 120 rats completely independently of the magnitude of the fat deposits, (the alimentary tract was removed from these rats before analysis). They interpret this as indicating that the tissue laid down with fat does not have a very different composition from that of the fat free body as a whole. Because in extremely fat animals

there is only a small percentage of the total water in the fatty tissue, this should make little difference to the overall proportion of water. This argument is supported to some extent, by the analyses of Callow (1947), who showed that the water content of muscular tissue was about 78% on a fat free basis, and of fatty tissue was 81-82% on the same basis. That is, there was not a large surplus of water in the fatty tissue.

On the basis of 256 eviscerated cattle from other experimenters including Murray and Moulton, Reid et al. (1955) estimated that these bodies contained 72.91 ± 2.01% water on a fat free basis. There was a highly significant correlation between age and percent water (r=-0.46), percent protein (r=+0.44), and percent ash (r=+0.43) in the fat free body. In rats (Ashworth and Cowgill, 1938) and in chickens (McNally, 1955) it has been shown that the fat free body composition is relatively constant. It is of interest to note that in every experiment with the exception of the rat studies quoted above, the body referred to is the body without the viscera. The only evidence to justify generalising to the whole body from the eviscerated body is with regard to fat. In 21 of the series of guinea pigs analysed by Pace and Rathbun (1945), it was shown that the fat content of the whole body is equivalent to that of the eviscerated carcass over the entire range examined, (r=0.989). This indicates that fat is probably laid down proportionately in the viscera and the remainder of the body. This applied over a range of 3-22% fat in the body. Lush (1926) also found a linear correlation of r=0.995 between body fat in the entire live animal, and fat in the boneless carcass. This would suggest that fat is laid down in the viscera and the carcass in a constant ratio; the ratio in which it was partitioned between the two was not stated. In both the above cases the correlation is between the part and the whole. **(Lush was working with cattle).**

In no direct experiment has the relationship been elucidated between the water content of the viscera on a fat free basis, and the eviscerated body on the same

basis. Callow (1947) has estimated that 78% of muscle on a fat free basis is water as compared to the figure of 72-73% water on a fat free basis for the eviscerated body reported by various workers. This difference can probably be attributed to the presence of bone, which has a low percentage water, and therefore must lower the overall water percentage in the fat free eviscerated body. This argument does not, however, apply to the viscera, which might be expected to have a higher water percentage on a fat free basis than the eviscerated body, if Callow's (1947) figure of 78% water applies to smooth muscle and organ tissue as well as skeletal muscle. This could raise the overall percentage body water on a fat free basis, as the viscera forms a considerable portion of the total body weight. Hankins et al. (1939) report that the viscera accounts for 20-40% of b ody weight in pigs, and in ruminants values of 40-55% of total body weight are common.

It is therefore of interest to note that Kraybill et al. (1951) estimated body fat from body water by the antipyrine method and used the factor of 73.2%. They related this to body fat estimated by the specific gravity method and to separable fat and ether-extract of the carcass as estimated from the three rib cut. Good agreement was obtained by all methods. However, the agreement between the specific gravity and body water methods may not be a check by two entirely independent approaches. As Lesser, Blumberg and Steele (1952) point out: "Calculation of body fat from specific gravity, involves the assumption of a specific gravity of 1.099 for lean body mass; calculation of body fat from total body water involves the assumption that lean mass is 73% water. These assumptions far from being independent ones, may be essentially the same, namely that 27% of mixed body solids dissolved and suspended in water yield a substance with a specific gravity of 1.099."

It would thus seem desirable to directly check the water content of the viscera before a figure of 72-73% of the fat free body weight may be validly regarded as water.

(D) CARCASS COMPOSITION

(1) Carcass weight

One of the simplest indices of carcass composition would appear to be carcass weight. Clarke and McMeekan (1952) report that within quality grades of lamb and mutton carcasses, there is a decrease in the proportion of bone and muscle, and an increase in the proportion of fat with increasing weight. These changes are also suggested by the work of McMeekan (1940) with the pig.

(2) Percentage cuts

This is a method of determining carcass components employed in the U.S.A., probably because certain parts of a carcass bring higher prices than others, e.g. the rump and loin are high priced in beef carcasses and the aim in breeding and feeding is to maximise these higher priced cuts. Workers using this technique include Whiteman et al. (1951) using the pig and Green (1954) for cattle. The big advantage of the technique seems to be that the meat can be sold at the completion of weighing. The method appears to lack precision and will not be discussed further.

(3) Dissection work (British)

This method was developed at Cambridge, and divides the carcass into fat, muscle, bone and tendon plus waste. This dissection method gives carcass composition in terms of the factors in which the consuming public are interested. Most of the work is based on a technique developed by Hammond (1932) in the sheep. A good description of the methods has been given by Pálsson (1939) for the sheep. The method has been used extensively, (McMeekan, 1940, on the pig; Pomeroy, 1941, on the pig; Wallace, 1948, on the sheep; Pálsson and Vergés, 1952, on the sheep; Clarke and McMeekan, 1952, on the sheep.)

(4) Dissection work (American)

By this method the carcass is divided into separable fat, muscle and bone and it was probably developed for cattle work. It has been described by McMeekan (1942)

as "butcher dissection" and Lush (1926) indicated that the techniques used are not completely standard. A description of this work is given by Hankins (1953) but the actual dissection methods do not seem to have been specified in the literature.

The earliest reports on the use of this technique seem to come from Missouri data on 33 steers and 3 cows, (Moulton, 1921, 1922a, 1922b, 1923; Towbridge, 1915, 1918; cited Hopper 1944), and Hopper collected and statistically analysed all suitable data, (92 cattle). Further statistical analyses have been carried out on a larger number of cattle of mixed breeds from the stored data of many experiments, by Hankins and Howe (1946), and their publication and that of Hopper (1944) are the standard references on beef cattle.

Cover et al. (1944) gives data on separable fat in lambs, while Hankins (1947) provides complete dissection data for the same species.

(5) Chemical analyses on the edible carcass components

Chemical analyses of the boneless meat gives the composition in terms of water, ether-extract (chemical fat) and fat free residue which is considered for practical purposes as protein by some workers, (Barnicoat and Shorland, 1952), or as nine-tenths protein (Callow, 1947) on the evidence of Bate-Smith (1942). In some American studies the Kjeldahl-Gunning Arnold method of analysis is followed for protein determination, (Hankins, 1946). Some workers also determine ash, (Hopper, 1944.)

Percentage ether-extract is highly correlated with carcass percent dissectible fat, (Hopper, 1944, for cattle; Shorland et al., 1947, for sheep).

With any chemical studies it must be remembered that the problem of sampling is involved; the chemical work being done on a very small sample of the total. Whiteman et al. (1953) showed that sampling methods can be an important source of error.

A refinement of the chemical approach has been used in a series of papers by Callow (1947, 1948, 1949, 1950) who analysed the dissected components from several

Cambridge carcass studies and interpreted his results in terms of growth and fattening of animals. Chemical data are particularly important for fatty tissue where the proportion of chemical fat may vary within wide limits.

(6) Chemical work on the complete carcass

Apart from small animal work, this has not been a practical procedure in the large meat animals until the advent of the method demonstrated in this laboratory using the meat bandsaw, (Barton and Kirton, 1956). A knowledge of the chemical components of the complete carcass is necessary for specific gravity correlations, and for nutritional and efficiency studies. In such studies, the energy content of a carcass is related to its chemical fat content, rather than to dissectible fat which varies in its proportions of chemical fat.

CHAPTER III

MATERIALS AND METHODS

(A) SELECTION OF EXPERIMENTAL ANIMALS

(1) Aims of selection

In this experiment fat animals were required and these were selected by picking heavy ewes within as narrow a liveweight range as possible. The underlying assumptions were that animals of the same liveweight should have approximately the same dressing-out percentage and therefore carcass weight, and also ewes of the same carcass weight should have approximately the same carcass composition. It was planned to apply treatments to groups of ewes with the same initial carcass composition, thereby aiming to demonstrate treatment effects on the carcass at the end of the investigation.

(2) Selection of animals

Fifty 6-year old shorn Romney-crossbred ewes of known history were selected on 13th December, 1955. They were chosen from 111 cull ewes of this age, from the Massey College Romney Sheep Breeding Flock. The initial range of liveweight of the cull ewes was 105 lb. to 179 lb., from which 50 averaging 147 lb. liveweight and ranging from 136 lb. to 163 lb. were selected. With an assumed dressing out percentage of 50, this should have brought a proportion of the carcasses to 73 lb. and over in weight. At this weight carcasses are commercially classed as manufacturing meat, mainly because of excessive fatness.

(B) PRE-EXPERIMENTAL MANAGEMENT

The selected ewes were run with other experimental sheep until the commencement of the experimental period of the 17th of January, 1956. Owing to the dry conditions prevailing following initial selection, and the fact that these animals had walked a considerable distance and eaten little just prior to reweighing, they lost weight over the pre-experimental period. The mean weight had fallen to 132.5 lb., a drop of 14.5 lb. in 35 days, with a range of liveweight of 110 lb. to 153 lb., at the time

of allotment to experimental groups.

(C) HORMONE USED

A stock of 30mg. implant tablets of purified l-thyroxine was kindly supplied by Glaxo Laboratories.

(D) EXPERIMENTAL DESIGN

The following design was used with ten groups each of five sheep. The abbreviations which may be used throughout this thesis are indicated.

Thyroxine treatment	Plane of nutrition	
	Normal plane (NP).	Low plane (LP).
	Control beginning of experiment (CB).	
	Control end of experiment (C:NP).	Control end of experiment (C:LP).
Low thyroxine (LT).	150mg. thyroxine implanted (LT:NP).	150mg. thyroxine implanted (LT:LP).
Medium thyroxine (MT).	210mg. thyroxine implanted (MT:NP).	210mg. thyroxine implanted (MT:LP).
High thyroxine (HT).	270mg. thyroxine implanted (HT:NP).	270mg. thyroxine implanted (HT:LP).
Daily thyroxine (DT).		5mg. thyroxine daily (DT:LP).

(1) Plane of nutrition

It was decided to include two levels of nutrition because a low plane of nutrition is known to reduce body weight. Evidence from the literature suggests that a high plane of nutrition can counteract the body weight reducing effects of hyperthyroidism. The normal plane of nutrition (NP.) consisted of full time grazing on adequate pasture, and the low plane of nutrition (LP.) consisted of 23 hours per day on a grass free yard. The other hour per day was spent on adequate pasture as was provided for the normal plane sheep. The low plane treatment was slightly modified during the experimental period because of two deaths.

(2) Thyroxine treatments

Although much information is available on the use of iodinated compounds, there is very little evidence available in relation to dosage of a known quantity of l-thyroxine. Henneman et al. (1955), using an isotope technique, postulated secretion rates of up to 0.33mg. l-thyroxine per day in Shropshire and Hampshire ewes and noted great variation between individuals. Hart (1955) reported on the use of l-thyroxine tablet implants of up to 100mg., which appear to have caused losses in liveweight of about 10 lb. in his sheep over a period of three weeks. No data were available on the rate of uptake of thyroxine from implants.

A preliminary experiment was carried out with two Romney-crossbred ewes implanted with 150mg. and 180mg. of l-thyroxine respectively and including 9 days of semi-starvation. The results were as follows:-

Ewe No.	Thyroxine implant	Liveweight		Weight loss	Days
		Beginning	End		
23/53	150mg.	181 lb.	153 lb.	28 lb.	36
194/50	180mg.	173 lb.	163 lb.	10 lb.	35

Thus this evidence, and all reported evidence of thyroxine administration and of secretion rates, suggests great variability of response. It is also known that high thyroxine dosage is toxic.

It was decided to use three levels of thyroxine implant to see if response to treatment was linear. The previously highest reported level of implantation was 100mg. which produced a weight loss below that which it was hoped to achieve in this present experiment. Therefore, levels of 150mg., 210mg. and 270mg. implants of l-thyroxine were used.

In order to obtain information on the rate of uptake of thyroxine from the implants, a daily thyroxine injection group was included for comparison with implanted groups. A dose rate of 5mg. l-thyroxine per sheep per day was used. A thyroxine

solution of known concentration was prepared from the 30mg. thyroxine tablets. On the evidence of Henneman et al. (1955), and assuming no breed differences, this is likely to be between 15 and 250 times the normal physiological level. These DT:LP sheep were penned with the LP. sheep to facilitate injection and regular inspection. During the course of the experiment, the daily injection treatment was modified as described in section (F).

(3) Allotment to treatment groups

The ewes were weighed on the 17th January, 1956 and alloted to their treatment groups by restricted randomisation (except for ewe 294. This ewe had become very lame during the pre-treatment period and so was alloted to the control group at the beginning of the experiment. The animals in this group were all killed the following day). The ewes were listed in order of weight and divided into five groups of 10 sheep, i.e. 10 lightest to the 10 heaviest. These five groups were then, with the above mentioned exception randomised to the ten treatment groups, by means of a table of random numbers. This resulted in ten groups of approximately equal average liveweight.

(4) Duration of experiment

The work of Blaxter (1948) and others suggested that quick results could be obtained and it was therefore decided to run the experiment for 21 or 28 days. If sufficient weight losses were not produced over the shorter period, the experiment was to run for 28 days. The danger of thyroxine toxicity was another reason for keeping the duration of the experiment flexible. With the large body of data to be collected at slaughter, involving 45 ewes, it was necessary to spread killing over 3 days. The timing of the experiment is indicated below.

Group	Date started	Date slaughtered	Duration (days)
CB.	[illegible]	18/1/56	--
DT:LP	18/1/56	15/2/56	28
C:NP	18/1/56	15/2/56	28
LT:NP	19/1/56	16/2/56	28
MT:NP	19/1/56	16/2/56	28
HT:NP	19/1/56	16/2/56	28
C:LP	20/1/56	17/2/56	28
LT:LP	20/1/56	17/2/56	28
MT:LP	20/1/56	17/2/56	28
HT:LP	20/1/56	15/2/56	26+

+This group was slaughtered two days early as one ewe was showing signs of treatment stress and it was feared she would not last the full 28 day period.

(E) METHOD OF IMPLANTATION

The animals to be implanted were yarded in the morning and a patch of three to four inches in diameter, just behind the left shoulder and mid way up the side, was clipped to the skin with scissors, and washed with a Cetavlon solution. In the afternoon each animal was held in turn on its right side by two men, and the operator (the author), shaved the clipped patch with a safety razor and applied tincture of Zephiran.

A half inch incision was made through the skin with a scalpel. By blunt dissection a pocket was made under the skin and the required number of 30mg. l-thyroxine tablets were implanted. Implanting was by means of a glass rod, in a loaded glass tube, from which the tablets were ejected into the prepared pocket. The incision was sutured by two stitches and a powdered sulpha drug was applied.

(F) MANAGEMENT AND RECORDS DURING THE EXPERIMENTAL PERIOD

Liveweights were taken several times throughout the course of the experiment, and at more frequent intervals as the experiment progressed. A daily check was made on the appearance of all animals. The low plane sheep had water available ad lib. The high plane sheep grazed two paddocks alternately, one of which had a water trough. When grazing in the other paddock these high plane sheep were taken to water daily. The low plane animals were permitted to graze for an hour each evening, with certain modifications.

After 16 days of daily injection routine (total of 80mg. l-thyroxine injected), ewe number 165 started showing signs of weakness and was not grazing at the completion of the hour on pasture. At this stage the daily injection treatment was stopped for all ewes in this DT:LP group. On the night of the 17th day, ewe 165 died and on the next night another DT:LP ewe (341) started showing signs of weakness and was slaughter-

ed. The stronger ewes in the DT:LP group, numbers 398 and 557, received further 5mg. injections on the 23rd and the 26th day of the experimental period (see Fig. 1), bringing their total to 90mg. of thyroxine over the 28 days.

As the normal plane sheep were only starting to show thyroxine effects on body weight after 21 days, it had been decided to run the experiment for the full 28 days. In view of the two deaths, it was suspected that the combined thyroxine-low plane treatment might prove too severe for the implanted sheep also, and so the one hour daily pasturing was increased to a two hourly period. As the low plane control sheep started gaining weight on two hours daily pasturing, all LP. sheep were cut back to an hour and a half grazing, see Fig. 1. However, two days later, grazing had once again to be increased to two hours until the end of the experimental period.

(G) SLAUGHTER TECHNIQUES AND RECORDS

The animals to be slaughtered were penned at 1 p.m. on the day prior to slaughter, and that same afternoon taken to the College abattoir. At 9 a.m. the following morning slaughtering commenced. The liveweight of each animal was recorded and then it was killed by cutting its throat, bled, and the carcass was dressed according to commercial practice, with the exception that the kidneys were removed.

The following information, additional to liveweight, and involving six workers, was recorded for each ewe:-

(1) Hot carcass weight minus kidneys.
(2) Wt. left and right fore metacarpal bones.
(3) Wt. stomachs and oesophagus full.
(4) Wt. stomachs and oesophagus empty.
(5) Wt. of contents by difference.
(6) Wt. of small and large intestines full.
(7) Wt. of small and large intestines empty.
(8) Wt. of contents by difference.
(9) Wt. of both kidneys.
(10) Wt. of heart.
(11) Wt. of liver (without gallbladder).
(12) Wt. of omental fat.
(13) Wt. of mesenteric fat.
(14) Wt. of spleen.
(15) Wt. of thyroid gland.
(16) General comments on carcass and organs.

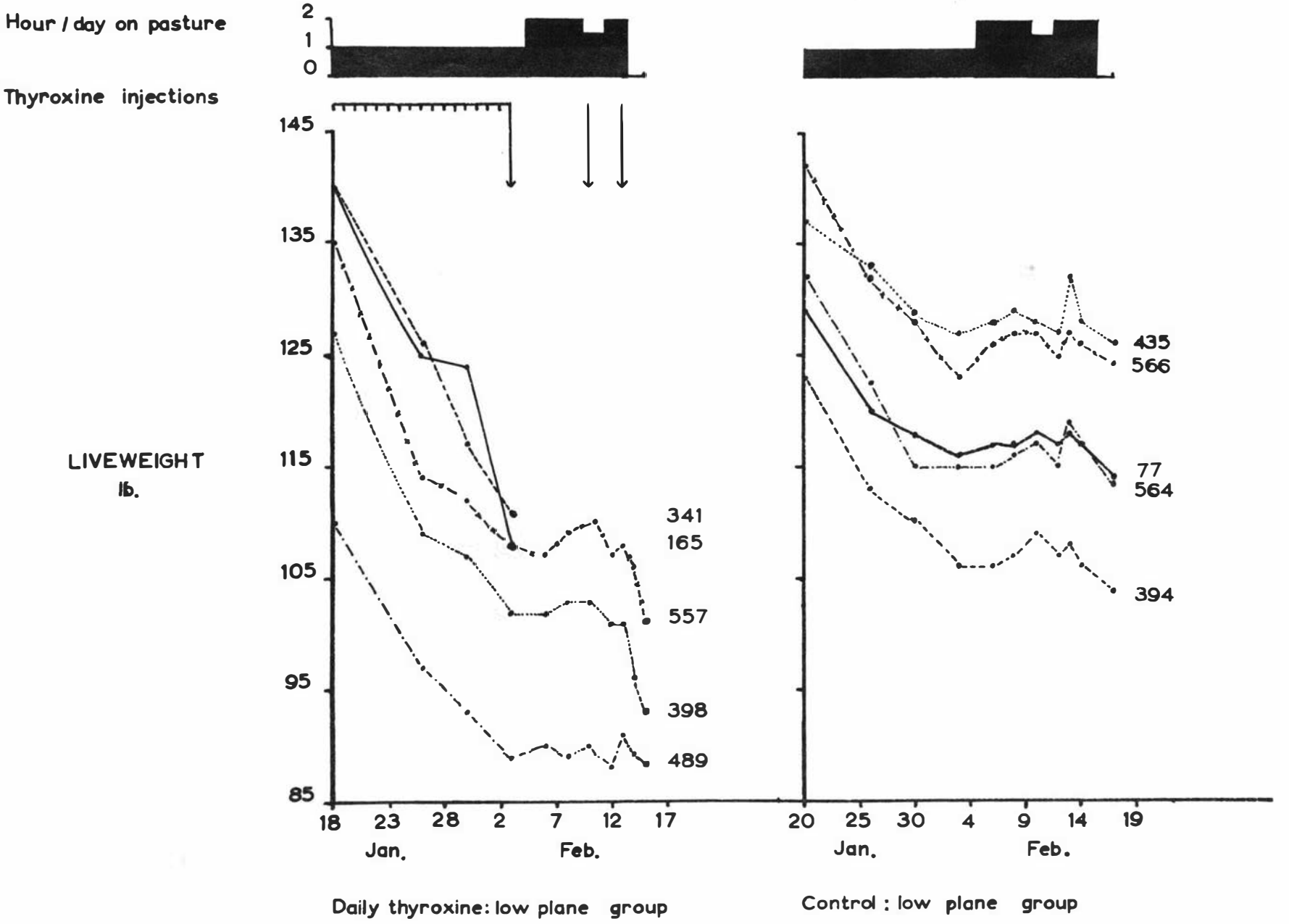

FIG. 1. TREATMENT EFFECTS ON LIVEWEIGHTS OF DAILY THYROXINE AND CONTROL LOW PLANE EWES.

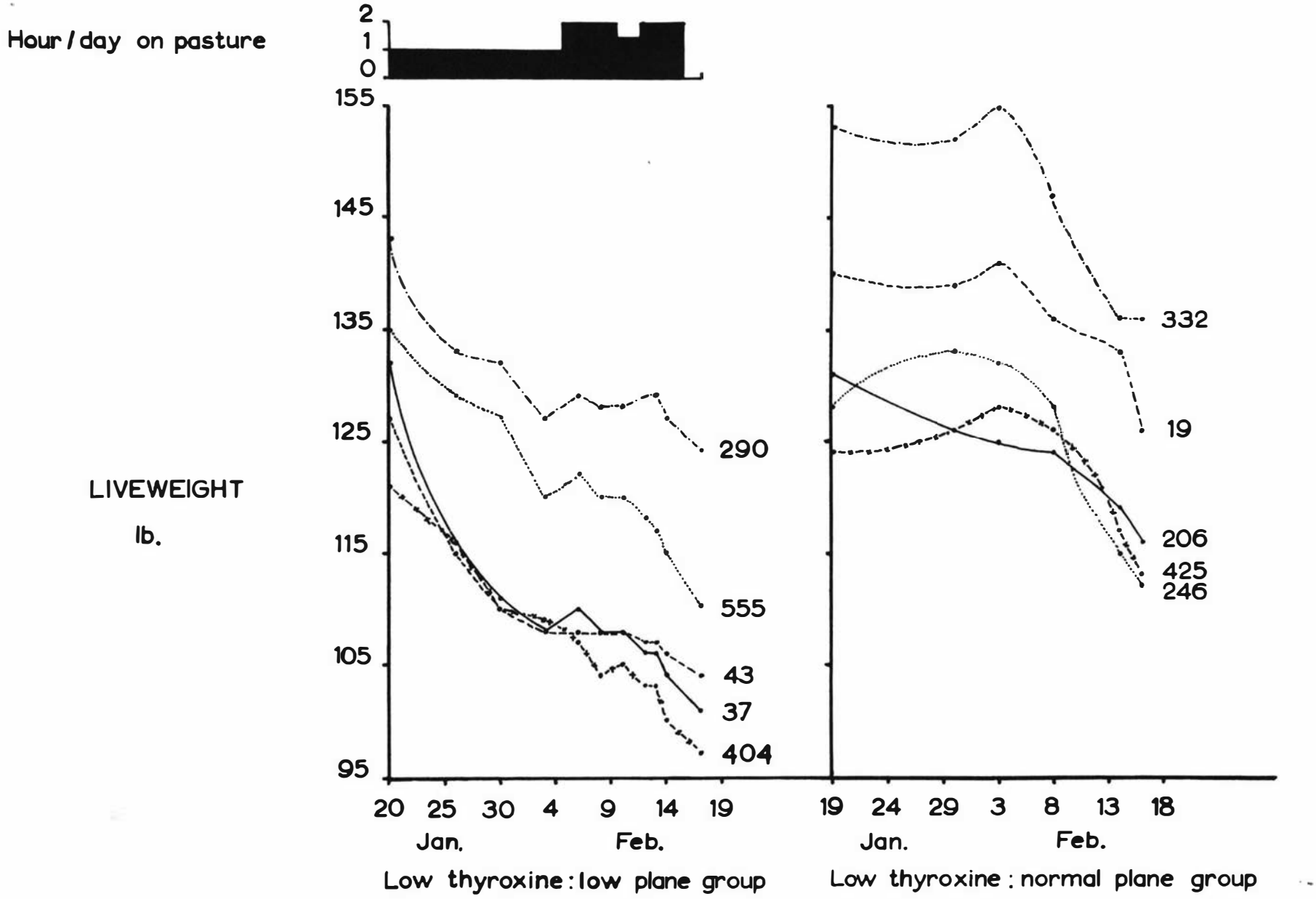

FIG. 1a. TREATMENT EFFECTS ON LIVEWEIGHTS OF LOW THYROXINE N.P. AND L.P. EWES

* Mesenteric fat includes the fat from the mesentery, lymph glands and the fatty tissue removed from the large intestinal surface.

The residual implants from 15 HP. sheep were collected from the skin and/or from the shoulder site of the carcass, for residual thyroxine determinations. At approximately 4 p.m., the carcasses were hung in the chiller on gambrels of standard width for overnight storage.

(H) POST SLAUGHTER MEASUREMENT AND SPECIFIC GRAVITY DETERMINATIONS

The following morning between 8 and 9 a.m., the cold carcasses were again weighed, to the nearest 0.1 lb., and various carcass measurements as described by Pálsson (1939) were taken. The weight of each carcass was then determined to the nearest gram completely submerged in water in a tank especially constructed for specific gravity purposes. The water temperature was 17-20°C and the surface temperature of the carcasses was 11-12°C.

The carcasses were then transported to the stores of the Manawatu Meat Company for freezing and storage.

(I) CARCASS DATA

(1) Carcass treatment

A brief report of some aspects of this work has been given by Barton and Kirton (1956). Carcass work started on 21st February, 1956. Normally, two frozen carcasses were brought each day except Friday, Saturday and Sunday from the stores. This arrangement made it possible to complete dissection and chemical work each week by Saturday evening.

Each carcass while still frozen, was divided down the middle of the back with a meat band saw, the left half being permitted to thaw for dissection work while the right half of the carcass was used for chemical analyses.

The right side of the carcass, while still frozen, was sliced into pieces $\frac{1}{8}$-$\frac{1}{4}$"

thick, using the meat bandsaw. Firstly the 9-10-11 rib cut was removed by cutting with the bandsaw midway between the 8th and 9th ribs, and midway between the 11th and 12th ribs. This cut was then sliced, minced and sampled for chemical analysis. The remainder of the side was sliced, minced, and the surplus mince from the rib cut was added before sampling for chemical analysis.

Samples of minced tissue from the sides of the C:NP, LT:NP and HT:NP ewes were sent to Dr. G.W. Butler, Plant Chemistry Laboratory, for microchemical iodine determinations.

(2) Chemical analyses

(a) Right half carcass analysis

As the material came through the mincer, it was regularly subsampled to give a total subsample of 4-6 lb. from half carcasses weighing from 21-39 lb. This subsample was reminced twice to ensure greater homogeneity. From this reminced subsample, six 50g. samples were weighed into butter moisture cups using a tripple beam balance with an accuracy of 0.2g.

For chemical methods, a modification of those reported by Barnicoat and Shorland (1952) was used. The samples were dried in an oven at 105-110°C for approximately 18 hrs. and weighed to give water loss by difference. The liquid fat was then decanted. Petroleum ether was added and the dried residue was crushed with a metal rod. After being allowed to settle, the ether was decanted, and this procedure was repeated twice more. The samples were then replaced in the oven to drive off the ether, and weighed to give the uncorrected fat weight (ether-extract) by difference, and dried fat free residue directly.

For the 48 half carcasses treated this way, the six samples per carcass gave the following results:-

	Mean ± S.E.M.	Coeff. Var.	Range
% water	42.21 ± 0.37	2.1%	31.8-52.7%
% ether-extract (uncorrected)	38.96 ± 0.45	2.8%	23.1-53.1%
% dried fat free residue (uncorrected)	18.83 ± 0.36	4.6%	15.0-24.6%

The low standard errors of the means, and coefficients of variation suggest that the sampling technique was satisfactory.

(b) Correction factors

From each sample of dried fat free residue, a subsample was taken and bulked for the 48 half carcasses. At the completion of the carcass analyses a portion of the bulked subsample was obtained by quartering and ground complete with bone, to a powder in a mill. Three samples of the powder were taken and Soxhlet extractions were carried out for 6 hrs. using petroleum ether. These gave values of 7.49%, 7.39% and 7.42% ether-extract from the dried fat free residues, and an overall weighted average (weighted by the weights of samples) of 7.43% ether-extract.

A further six samples of powdered dried fat free residue were taken and ashed in a muffle furnace to give the following ash percentages:-

25.97, 26.83, 26.04, 25.93, 26.01 and 25.53 (weighted mean = 26.00% ash).

These two correction factors were applied as indicated below to the mean value per half carcass of the dried fat free residue (d.f.f.r.).

% ether-extract = mean % ether-extract (uncorrected) + 7.43 d.f.f.r. %
% ash = mean % d.f.f.r. by 26.00
% protein = mean % d.f.f.r. - 26.00 d.f.f.r.% - 7.43 d.f.f.r. %

The correction increased the total % ether-extract per half carcass by 1-2%. The term "protein" in this case is in line with that of Barnicoat and Shorland (1952), although according to Bate-Smith (1942), the nitrogenous substances in meat comprise approximately 89% true protein.

(c) Other chemical work

The same chemical procedure as for the half carcass samples was applied to each 9-10-11 rib cut sample. The following correction factors were determined by the same procedures as employed in the half carcasses, and applied to % dried fat free residue of the rib cut.

% ether-extract correction = 8.50 d.f.f.r. %
% ash correction = 21.83 d.f.f.r. %

Following dissection, chemical analyses were also carried out on dissected muscle plus tendon and waste from the leg, the loin and the rib cuts. The dissected fat from the leg and from the rib cut was analysed chemically. Soxhlet correction factors were applied where appropriate to these data also. The dissected fat from the loin and the perirenal fat were sent for analyses to Dr. F.B. Shorland (Fats Research Laboratory).

(3) Physical methods of analysis on the left half carcass

After thawing, the left side was divided into two portions by a cut between the last thoracic and first lumbar vertebrae and following the curve of the rib to the flank. The measurements reported by Pálsson (1939) were made on the anterior surface of this section and recorded for further study. A 9-10-11 rib cut was removed by cutting mid way between the 11th and 12th ribs and parallel to the ribs, and taken through the vertebrae with a saw, and straight to the flank on the outer limits. A similar cut was made between the 8th and 9th ribs.

The perirenal fat and fat from the pelvic cavity (channel fat) were removed and weighed.

The leg joint was removed as described by Pálsson (1939). The loin was removed by cutting between the second to last and last lumbar vertebrae; the remainder of the jointing of this part being carried out as described by Pálsson (1939). This resulted, over the series of sheep dissected, in a loin averaging 5.5 vertebrae as compared to a loin averaging 6.5 vertebrae in stored data of the Sheep Husbandry Department collected from loins removed by Pálsson's method. The joints were weighed.

It was possible to estimate the dissectible total constituents of the carcass from the dissected leg plus loin. Estimating equations were calculated between leg plus loin constituents and the same constituents in the totally dissected carcasses of 25 Romney crossbred ewes, (stored data). The stored data were of wider carcass weight range than the present data. The doubled weight of the half loin from the present experiment, when used in the estimating equation, is likely to underestimate total

carcass constituents owing to the method of jointing which gives a smaller loin than the method of Pálsson. It is however, unlikely to effect the variability and ranking order of this data.

Specific gravity determinations by underwater weighing were made on the leg, loin and rib cuts.

The joints were then reweighed and dissected into fat, muscle, bone and tendon plus waste as described by Pálsson (1939). The dissected components were weighed and then minced and sampled for chemical analyses as described earlier.

(J) STATISTICAL METHODS

The analysis of variance technique as described by Snedecor (1946, p.275) was used to test the significance of the treatment effects. This analysis was used to indicate the effects of thyroxine, plane of nutrition and the interaction between them. The groups indicated below were included in the analysis of variance

Control beginning+

Control end NP.	Control end LP.
Low thyroxine NP.	Low thyroxine LP.
Medium thyroxine NP.	Medium thyroxine LP.
High thyroxine NP.	High thyroxine LP.

Daily thyroxine LP.+

+Groups excluded from analysis

The CB. group was excluded because much of the data from this group were not strictly comparable to that which had been collected from the remaining groups following the experimental period. As two DT:LP sheep died, some data were missing from this group, and for this reason it was not included in the statistical analyses.

The standard error of the treatment means was derived from the error mean square of the analysis of variance, and was used to estimate the 5% and 1% confidence limits for the group means. Strictly speaking, these confidence limits apply only to the eight groups included in the analysis of variance, but they do indicate treatment effects in the remaining groups.

Since the accuracy of tests of significance in the analysis of variance is dependent on homogeneity of the variances between the experimental groups, Bartlett's test (Snedecor, 1946, p.249) was applied where homogeneity appeared to be doubtful.

CHAPTER IV

TREATMENT EFFECTS ON LIVEWEIGHT AND ANIMAL HEALTH RESULTS.

(A) TREATMENT EFFECTS ON LIVEWEIGHT

The liveweight group means are presented in Table 1.

Table 1

Liveweight (lb.) at the beginning and end of the experimental period. Group means and standard deviations.

Group	Beginning of experiment			End of experiment		
	Mean	S.D.	Range	Mean	S.D.	Range
CB	130.4	11.2				
C:NP	132.4	6.7		130.2	8.5	
C:LP	132.6	7.3		116.4	8.9	
LT:NP	135.2	11.6		120.6	11.0	
LT:LP	131.6	8.3		107.2	10.5	
MT:NP	132.8	7.5		115.6	6.9	
MT:LP	134.8	10.9		111.2	8.5	
HT:NP	133.0	7.8		116.8	6.6	
HT:LP	132.0	8.2		108.8	8.2	
DT:LP	130.4	12.6		94.0(3)+	6.6(3)+	
50 sheep	132.2	8.7	110-153			88-142

+In tables throughout this thesis a figure in brackets will indicate the number of observations upon which the group mean and standard deviation is based, when this differs from the normal of five observations. In this case the death of two sheep in the DT:LP group, before the completion of the experiment is the reason for their omission from the mean.

The general group liveweight trends over the experimental period have been plotted in Figure 2 and the individual variability of response to treatment is shown in Figure 1.

Statistical analyses revealed that both the thyroxine treatment and the low plane of nutrition had produced highly significant weight losses.

Table 2

The mean liveweight loss of the treatment groups (lb.).

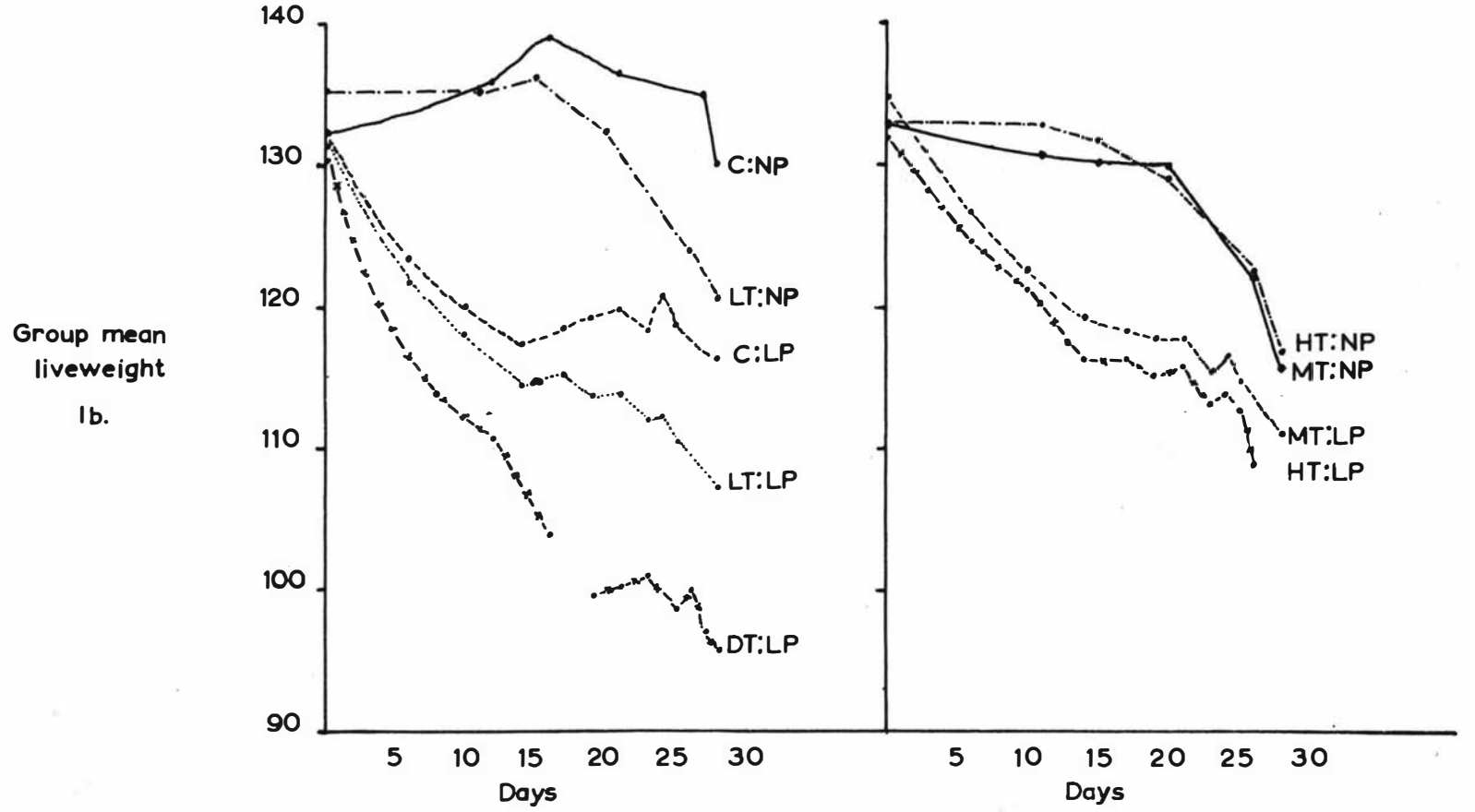

FIG. 11. Effects of thyroxine and plane of nutrition on liveweight.

Group	Mean weight loss	Percentage weight loss
C:NP	2.2	1.7
C:LP	16.2	12.2
LT:NP	14.6	10.8
LT:LP	24.4	18.5
MT:NP	17.2	13.0
MT:LP	23.6	17.5
HT:NP	16.2	12.2
HT:LP	23.2	17.6
DT:LP	30.0 (3)	24.2 (3)

Table 3

Analysis of variance of liveweight change (lb.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	857.8	285.9	14.6	ss
Plane of nutrition	1	864.9	864.9	44.2	ss
Treatment interaction	3	90.1	30.0	1.5	ns
Within subclass	32	625.6	19.6		
Total	39	2438.4			

Note: ss = significant at the 1% level ($p < 0.01$)
s = significant at the 5% level ($p < 0.05$)
ns = not significant ($p > 0.05$)
This nomenclature will be used throughout to denote significance levels.

Standard error of the treatment means = 1.997 lb.
5% fiducial limits = $\pm$ 4.04 lb.
1% fiducial limits = $\pm$ 5.44 lb.

That no difference in weight loss can be attributed to level of thyroxine implantation can be seen from Table 2. The difference lies between the control ewes and those implanted. For the normal plane and low plane implanted ewes respectively, these weight losses averaged 0.57 and 0.85 lb. per day. However, the daily injection treatment has produced a greater weight loss (1% level) than the thyroxine implantation. Highly significant weight losses due to the low plane of nutrition are present at all levels of thyroxine treatment.

Table 4 is presented to show the rate of liveweight loss which proved dangerous.

Table 4

Weight loss in the DT:LP group

Ewe No.	Weight loss (lb.)	% weight loss	Time	
165	32	22.9	16 days+	Died
341	29	20.7	16 days	Died
398	34	26.8	28 days	
489	22	20.0	28 days	
557	34	25.2	28 days	

+16 days was the time at which the last liveweight was taken on these ewes although their deaths occurred later.

It must not be forgotten that all ewes had lost on the average 14.5 lb. during the pre-experimental period of 35 days, which loss was 9.9% of the mean pre-experimental weight. The DT:LP group had lost 28.8% of their body weight over the total pre-experimental and experimental periods. From Table 4 it can be seen that the loss of approximately 2 lb. liveweight per day for 16 days proved lethal for two ewes while the remaining three ewes which lost about 1 lb. per day for 28 days survived.

(B) ANIMAL HEALTH

(1) The DT:LP group

The combination of 5mg. l-thyroxine daily, on a low plane of nutrition proved to be too severe, as ewe 165 died and ewe 341 was slaughtered *in extremis* during the course of the experiment. It was observed in the process of handling the DT:LP sheep for injection, that all these animals became noticeably weaker than the other LP. animals. The respiration rates of the DT:LP ewes rose to values of over 100 per minute, but because of their rapidity, it became impossible to obtain accurate counts.

The first symptoms in the above mentioned two ewes was that they stopped grazing during the hour on pasture. At this stage they appeared to experience difficulty in standing. A postmortem examination revealed an almost complete absence of food in their gastrointestinal tract, apart from a small quantity of liquid in the rumen. Postmortem examination also revealed abundant fatty tissue in the subcutaneous and internal fat depots. The articulating surfaces of the cannon bones, and of the other long bones examined, were tinged blue which was in contrast to the creamy-white

colour of the articulating surfaces of the bones of the control sheep.

Measurements were taken on the influence of 5mg. l-thyroxine injected daily, on the metabolic rate of a Romney ewe fed hay ad libitum. This animal had previously been involved in metabolic studies. The oxygen consumption and respiration rate of the ewe were measured via a tracheal cannula, by the technique of Cresswell (1957). Evidence is being accumulated by this worker which shows that the metabolic rate remains relatively constant for an individual animal over a liveweight change of ± 10 lb. The following were the results of the thyroxine treatment:-

Date	Oxygen consumption litre O_2/5 min. (N.T.P.)	Respiration rate	Liveweight (lb.)	Treatment
5 day average	1.1	30 / min.	65 (approx.)	
28th Jan.	1.0	35	-	
29th "	1.0	50	-	
30th "	0.9	30	-	5mg. thyroxine
31st "	0.9	30	62	10mg.
1st Feb.	1.0	60	59	5mg.
2nd "	1.4	70	-	5mg.
3rd "	1.4	100	59	5mg.
4th "	1.8	110	59	stopped
5th "	1.6	110	58	"
6th "	1.1	80	60	"
8th "	1.1	40	61	"
20th Feb.	1.2	50	75	
24th "	1.0	40	-	
26th "	+	60	70.5	5mg. thyroxine
27th "	1.1	45	68	5mg.
28th "	1.3	50	63.5	5mg.
1st March	1.5	90	-	5mg.
2nd "	1.6	80	60	5mg.
3rd "	1.5	100	57	stopped
4th "	1.3	100	60	"
5th "	1.2	90	60.5	"
6th "	1.2	80	64	"
7th "	1.0	60	67	"
8th "	1.0	60	66	"

+An air leak developed and so this reading was discarded. This did not effect respiration rate.

The treatment was applied only for short periods because the ewe used was a valuable experimental animal. The results show that for this animal, the oxygen

consumption was increased by at least 50% (it was increasing when the treatment was stopped in both cases). The respiration rate was at least doubled and liveweight was reduced by the thyroxine treatment. A lag of two days occurred between the time of the first injection and the time that the effects of the thyroxine started to show up. These effects could still be detected on the respiration rate 3-4 days after treatment had ceased. These results indicate the seriousness of the daily injection treatment, even when the animal is on an adlib. diet.

(2) Low plane sheep other than DT:LP group

It was observed that the C:LP sheep adapted themselves well to the experimental conditions, as was indicated by the maintenance of an almost constant body weight, following an initial drop. All low plane sheep spent most of the day in a recumbent position. A high respiration rate was observed among some of the thyroxine implanted sheep. During the last four days of the experiment, ewe 55 in the HT:LP group was showing signs of weakness which necessitated the slaughter of this group at the end of 26 days, instead of 28 days as planned. Ewe 55 may not have survived the full experimental period since she had the lowest weight of gastrointestinal contents of all the ewes slaughtered at the completion of the experiment, see (1) The DT:LP group.

(3) Normal plane sheep

No symptoms resulting from thyroxine implantation were observed in these sheep until the latter part of the experiment. Five of the fifteen implanted NP. sheep became very daggy while none of the five control sheep were affected. The implanted ewes were usually eager to drink when the NP. sheep were watered and were always first to the water trough.

Toward the end of the experiment one of the HT:NP ewes was obviously panting and spent much of her time lying down.

(4) General observation

It was observed at slaughter that all of the thyroxine treated sheep were suffering from wool break at skin level. There was no wool break in the control

sheep.

DISCUSSION

The results of the experimental treatments demonstrated that both thyroxine and a low plane of nutrition have caused large liveweight losses. As the low plane of nutrition was largely defined in terms of liveweight loss, this latter result was not altogether unexpected.

A surprising feature of the experiment was that there was no demonstrable difference in liveweight loss between the different levels of thyroxine implantation, namely 150mg., 210mg., and 270mg. of l-thyroxine. The higher weight losses in the DT:LP group show that the lack of difference between the level of thyroxine implanted groups does not result from an upper limiting rate of weight loss being reached in these sheep. This would rather suggest that the limiting factor is likely to be the rate of uptake of thyroxine from the implants.

In comparison with other experiments on undernutrition, (Pomeroy, 1941; Robinson, 1948; and Franklin, 1952), and on thyroxine implantation, (Hart, 1955), the weight losses, in view of the short time involved, are high. A weight loss of up to 1lb. per day seemed to be safe for the 28 days of this experiment, while one of 2 lb. per day proved lethal. It should be born in mind that all ewes had lost on the average 14.5 lb. prior to the beginning of the experimental period and group mean losses of up to 30.2 lb. liveweight occurred on top of the earlier pre-experimental loss.

The average effect of the low plane of nutrition on the control sheep as compared to the high plane control sheep was a loss of 0.50 lb. liveweight per day. The average effect of implantation on a high plane of nutrition as compared to the control sheep was a loss of 0.49 lb. liveweight per day. However, in those ewes subjected to both a low plane of nutrition and thyroxine implantation, the average daily loss of liveweight on the same basis, was 0.77 lb. This would suggest that the greater the rate of weight loss, the more difficult it is to achieve an extra

decrement; apparently the law of diminuishing returns applies.

The DT:LP ewes showed more marked signs of hyperthyroidism than the implanted sheep, as two ewes died and greater weight losses were recorded in the former group. From this it may be inferred that the implanted sheep were absorbing less than 5mg. l-thyroxine per day. An analysis of the residual implants from three HP. ewes implanted with 270mg. l-thyroxine revealed that approximately 150mg. remained, (Dr. Butler - personal communication). Not taking into account the losses in collecting the residual implants would indicate a maximum possible absorption rate of 4.3mg. per day in the high thyroxine ewes, if the rate of absorption is assumed even. The remaining two residual implants of the HT:HP group decomposed in storage and so were unsuitable for analysis.

Measurement of the metabolic rate in a ewe injected 5mg. thyroxine for 5 days, and on an ad libitum diet, indicated that the oxygen consumption had been increased by at least 50% and the respiration rate had been doubled as compared with the same ewe before treatment. This should indicate the severity of the treatment in the DT:LP group.

The main signs of hyperthyroidism in the living animals seemedto be, an increased respiration rate, indications of scouring in the normal plane sheep (suggested by the presence of dags), and an increased water consumption as indicated from behavioural observations. These symptoms are in line with those reported by Blaxter (1948, 1948a).

Further observations just prior to the death of the two DT:LP ewes that did not survive the experimental period, plus a postmortem examination of their gastrointestinal contents suggested that the severity of the DT:LP regime had resulted in a self imposed starvation. This postmortem inspection of the above mentioned two ewes also revealed plentiful fatty tissue in the subcutaneous and internal depots, as opposed to the observations of Blaxter (1948a). However, his wethers were considerably

lighter than the present ewes and so these wethers probably had less fatty tissue to start with.

CHAPTER V

TREATMENT EFFECTS ON CARCASS WEIGHT AND COMPOSITION

RESULTS

(A) CARCASS WEIGHT

The group means for carcass weight are presented in Table 5. An analysis of variance revealed no significant treatment effects on hot carcass weight.

Table 5

Hot carcass weight (lb.) Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	71.0	5.7			
C:NP	67.6	8.4	C:LP	60.7	6.2
LT:NP	62.8	5.7	LT:LP	56.0	7.1
MT:NP	63.8	5.4	MT.LP	61.7	8.3
HT.NP	59.3	4.5	HT:LP	60.4	5.5
			DT.LP	49.6(3)	7.3(3)

Table 6

Analysis of variance of hot carcass weight (lb.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	161.74	53.91	1.272	ns
Plane of nutrition	1	134.32	134.32	3.169	ns
Treatment interaction	3	113.46	37.82	0.892	ns
Within subclass	32	1356.41	42.39		
Total	39	1765.93			

However, the great variability of these data indicates that large differences are required before significance is reached. As in all cases the treatment groups have lower mean weights than the CB. or C:NP groups, it seemed possible that there were treatment effects which could not be demonstrated statistically. However, weight loss is known to effect the components of carcass weight differentially and so these were next checked for treatment effects.

(B) CHEMICAL COMPONENTS OF CARCASS WEIGHT

(1) Chemical fat

The analysis of variance of weight of chemical fat in the carcass is presented in Table 8. Before testing for treatment effects, Bartlett's test of homogeneity of variance was applied. This gave a χ^2 of 7.72 for 9 d.f., $p>0.5$, indicating that the hypothesis of equality of the variances is acceptable.

Table 7

Weight of chemical fat in the carcasses (lb.) Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	30.7	4.00			
C:NP	25.1	8.98	C:LP	23.8	4.73
LT:NP	25.6	3.73	LT:LP	21.7	6.27
MT:NP	27.2	3.70	MT:LP	27.5	8.11
HT.NP	21.1	4.48	HT:LP	24.4	3.81
			DT:LP	16.8(3)	6.67(3)

Table 8

Analysis of variance of weight of chemical fat in the carcasses (lb.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	121.12	40.37	1.19	ns
Plane of nutrition	1	1.40	1.40	0.04	ns
Treatment interaction	3	66.79	22.26	0.66	ns
Within subclass	32	1081.46	33.80		
Total	39	1270.77			

The thyroxine implantation and low plane of nutrition have caused no significant loss of carcass fat. However, the DT:LP sheep appear to have lost carcass fat.

A comparison between Table 1 and Table 7 indicates that body weight is not a good index of the state of fatness of the carcass. The CB. and C:NP groups of almost the same average liveweight at slaughter, differ on average by 5.6 lb. of carcass fat. This is a large difference.

(2) Fat free carcass weight

Both the thyroxine treatment and a low plane of nutrition have caused a highly significant reduction in weight of the fat free carcass.

Table 9

Fat free carcass weight (lb.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	39.2	2.45			
C:NP	41.0	1.30	C:LP	35.6	3.27
LT:NP	35.8	2.66	LT:LP	32.8	1.13
MT:NP	35.3	2.40	MT:LP	33.0	1.62
HT:NP	36.7	2.31	HT:LP	34.7	1.89
			DT:LP	31.4(3)	1.05(3)

Table 10

Analysis of variance of fat free carcass weight (lb.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	111.42	37.14	7.81	ss
Plane of nutrition	1	100.90	100.90	21.22	ss
Treatment interaction	3	18.36	6.12	1.29	ns
Within subclass	32	152.18	4.76		
Total	39	382.86			

Standard error of the treatment means = 0.975 lb.
5% Fiducial limits = ± 1.99 lb.
1% Fiducial limits = ± 2.68 lb.

The thyroxine effect of reducing the weight of the fat free carcass lies between the controls and the implanted sheep, and the latter sheep and the DT:LP group. There is no significant difference between the levels of thyroxine implantation, although there is a tendency for the high level of implantation to be less effective than the lower levels.

The low plane of nutrition reduced the weight of the fat free carcass between the control sheep and at all levels of thyroxine treatment. All in all, the treatments account for from 4-10 lb. of the liveweight loss.

The next stage of the analysis was to break down the fat free carcass into its

components of protein, water and ash to discover which of these show treatment effects. As the ash values were determined from a correction factor, they were not suitable for statistical analysis.

(3) Carcass protein weight

A low plane of nutrition reduced the weight of carcass protein, but no thyroxine effects were demonstrated.

Table 11

Carcass protein (lb.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	8.11	0.659			
C:NP	8.12	0.647	C:LP	7.17	0.772
LT:NP	7.62	0.499	LT:LP	6.87	0.154
MT:NP	7.60	0.789	MT:LP	7.12	0.508
HT.NP	7.76	0.652	HT.LP	7.22	0.537
			DT.LP	7.01(3)	0.358(3)

Table 12

Analysis of variance of weight of carcass protein (lb.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	0.8874	0.296	0.82	ns
Plane of nutrition	1	4.6444	4.644	12.90	ss
Treatment interaction	3	0.3329	0.111	0.31	ns
Within subclass	32	11.5257	0.360		
Total	39	17.3904			

Standard error of the treatment means = 0.2683 lb.
5% Fiducial limits = $\pm$ 0.548 lb.
1% Fiducial limits = $\pm$ 0.738 lb.

At the most, the loss of protein only accounts for the loss of about a pound of the fat free carcass weight. This is, however, a considerable proportion (approx. 12.5%) of the original total weight of protein.

(4) Carcass water weight

From the analysis of variance, Table 14, it can be seen that both thyroxine treatment and a low plane of nutrition caused highly significant weight losses.

Table 13

Carcass water (lb.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	27.9	1.54			
C:NP	29.7	0.99	C:LP	25.6	2.24
LT:NP	25.2	2.01	LT:LP	23.2	1.24
MT:NP	23.1	1.02	MT:LP	24.7	1.52
HT:NP	24.6	1.75	HT:LP	25.9	1.42
			DT:LP	21.7(3)	0.63(3)

Table 14

Analysis of variance of weight of carcass water (lb.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	86.606	28.87	11.55	ss
Plane of nutrition	1	49.841	49.84	19.94	ss
Treatment interaction	3	11.800	3.93	1.57	ns
Within subclass	32	80.116	2.50		
Total	39	228.363			

Standard error of the treatment means = 0.707 lb.
5% Fiducial limits = ± 1.44 lb.
1% Fiducial limits = ± 1.94 lb.

Once again no large differences are attributable to different levels of thyroxine implantation. The main treatment effect seems to be a loss of water in all groups as compared with the C:NP group, and the loss due to the low plane of nutrition is not clearcut between the implanted ewes. Thyroxine implantation has proved more effective on the normal plane of nutrition. The DT:LP group is once more significantly lighter than other groups. Water loss can account for up to 8 lb. of the loss in weight of the fat free carcass, as compared with the C:NP group. The lower weight of water in the CB. group as compared with the C:NP group can probably be accounted for by the droving and yarding the former sheep received for two days prior to slaughter.

An attempt was made to find out if the loss of water was a dehydration effect, or if it occurred in conjunction with tissue loss. Water has been suggested to compose approximately 72% of the fat free carcass weight in many species, and so the propor-

tion of water in the fat free carcass of these ewes was computed, and the results were statistically analysed as shown in Table 16.

Table 15

Water as a percentage of the fat free carcass. Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	71.22	1.248			
C:NP	72.34	1.494	C:LP	72.02	0.704
LT:NP	70.38	0.564	LT:LP	70.64	1.350
MT.NP	70.12	1.647	MT.LP	70.06	1.073
HT.NP	70.58	0.654	HT:LP	70.94	2.094
			DT:LP	68.97(3)	0.602(3)

Table 16

Analysis of variance of water expressed as a percentage of the fat free carcass.

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	24.65	8.22	4.86	ss
Plane of nutrition	1	0.04	0.04	0.00	ns
Treatment interaction	3	0.74	0.25	0.17	ns
Within subclass	32	54.18	1.69		
Total	39	79.61			

Standard error of the treatment means = 0.581%
5% Fiducial limits = $\pm$ 1.187%
1% Fiducial limits = $\pm$ 1.599%

It can be seen from Table 15 that thyroxine treatment has caused a dehydration of the fat free carcass. This raises the apparent anomoly of lack of a plane of nutrition effect on the proportion of water in the fat free carcass in contrast to the highly significant plane of nutrition reduction of water weight shown in Table 14. However, this effect is explained by the highly significant loss of protein on a low plane of nutrition. That is, the plane of nutrition effect is a loss of both protein and water in a constant ratio, probably in the form of muscular tissue, while the thyroxine treatment causes dehydration.

It is of interest to note that for the 15 control ewes, the carcass water formed

71.86% (range 70.2% - 74.0%) of the weight of the fat free carcass. This value is likely to be lower than the value for proportion of water in the fat free fresh carcasses due to storage shrinkage losses.

The value for carcass water on a fat free basis has been taken as synonymous with body water on the same basis by many workers and used to estimate body fat. Keys and Brožek (1953) have criticised this method on the grounds that on the evidence available at that time, carcass fat and proportion of carcass water on a fat free basis were significantly correlated. This present data seemed suitable to test whether this was also the case for the ewe.

Table 17

Correlations between water as a proportion of the fat free carcass (f.f.c.) and percentage and weight of carcass fat, in the ewe.

Variates	No. of ewes	Correlation
Water as % f.f.c. and wt. carcass fat	15 controls	r= 0.24 ns
Water as % f.f.c. and % carcass fat	15 controls	r= 0.26 ns
Water as % f.f.c. and wt. carcass fat	33 thyroxine treated	r= 0.16 ns
Water as % f.f.c. and % carcass fat	33 thyroxine treated	r= 0.15 ns

Because thyroxine reduced the proportion of carcass water on a fat free basis, these correlations were computed within the thyroxine treated animals and within the control groups. The results indicate that carcass water expressed as a proportion of the fat free carcass is independent of carcass fat in the ewe.

(C) PHYSICAL COMPONENTS OF CARCASS WEIGHT

The weights of dissectible fat and dissectible muscle in the ewe carcasses were estimated from the leg plus loin dissectible components of these same ewes. The relationship between the components of the leg plus loin and the same carcass components was calculated from stored data on 25 Romney cross-bred ewes, and applied to the pre-

sent experimental data.

Table 18

Relationship between dissectible components of leg+loin and the same carcass components for 25 ewes.

Dissectible fat (g.)

Dependent variate (weight of dissectible carcass fat, g.) = Y
Independent variate (weight of dissectible fat in leg+loin, g.) = X

Correlation coeff.	Regression equation
r= 0.9839	Y = 4.178X + 955.2 ($S_{y.x}$ = 655.7g.)

Dissectible muscle (g.)

Dependent variate (weight of dissectible carcass muscle, g.) = Y
Independent variate (weight of dissectible muscle in leg+loin, g.) = X

Correlation coeff.	Regression equation
r= 0.9725	Y = 3.695X + 1151.7 ($S_{y.x}$ = 462.6g.)

Table 19

Total dissectible fat+ in carcasses (lb.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	25.1	5.63			
C:NP	23.5	9.52	C:LP	20.4	5.94
LT:NP	20.5	3.30	LT:LP	18.0	4.97
MT:NP	25.1	4.60	MT:LP	24.1	7.56
HT:NP	18.8	3.54	HT:LP	21.0	2.34
			DT:LP	15.1(3)	6.10(3)

+For reasons discussed earlier (MATERIALS AND METHODS, I, 3.) this will be a slight underestimate.

The variability of dissected fat is high as it also was for chemical carcass fat. Only the DT:LP group appears to show a reduction in carcass dissectible fat. With muscle tissue on the other hand, the variability is low and the results are more clearcut.

Table 20

Total dissectible muscle+ in carcasses (lb.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	29.3	1.95			
C:NP	30.7	1.30	C:LP	26.7	3.17
LT:NP	27.9	1.56	LT:LP	24.6	1.10
MT:NP	26.5	2.33	MT:LP	25.3	1.91
HT:NP	27.9	2.29	HT:LP	25.4	1.10
			DT:LP	23.6(3)	2.46(3)

+For reasons discussed in MATERIALS AND METHODS, (I), (3), this will be a slight underestimate.

Table 21

Analysis of variance of carcass dissectible muscular tissue (lb.)

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	48.325	16.108	4.177	s
Plane of nutrition	1	73.902	73.902	19.165	ss
Treatment interaction	3	11.137	3.712	0.963	ns
Within subclass	32	123.384	3.856		
Total	39	256.748			

Standard error of the treatment means = 0.878 lb.
5% Fiducial limits = ± 1.79 lb.
1% Fiducial limits = ± 2.42 lb.

A low plane of nutrition has caused a reduction of muscular tissue in the C:LP ewes and at all levels of thyroxine treatment except the medium level. Thyroxine has reduced the weight of muscular tissue on the normal plane, but only in one implanted group and the DT:LP group on the low plane. No effects can be attributed to level of implanted thyroxine.

(D) TREATMENT EFFECTS UPON LEG, LOIN, RIB CUT AND PERIRENAL FAT

(1) Leg

An analysis of variance revealed a significant plane of nutrition effect on leg weight. This is to be expected as the major component of leg weight is muscular tissue, which the evidence so far reported suggests is the major tissue effected by the low plane.

Table 22

Leg wt. (g.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	3053.2	195.9			
C:NP	3039.4	269.2	C:LP	2821.4	264.0
LT:NP	2928.8	248.1	LT:LP	2616.2	163.9
MT:NP	2906.8	183.3	MT:LP	2879.4	229.6
HT:NP	2958.2	116.2	HT:LP	2843.4	191.7
			DT:LP	2155.5(4)+	122.8(4)

+The leg of ewe 341 was removed and dissected although most of the normal information was missing on this ewe. The ewe was killed after 18 days on the DT:LP routine and so is not strictly comparable to the remaining data.

Table 23

Analysis of variance of leg weight (g.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	145662	48554	1.058	ns
Plane of nutrition	1	282913	282913	6.166	s
Treatment interaction	3	115018	38339	0.836	ns
Within subclass	32	1468252	45883		
Total	39	2011845			

Standard error of the treatment means = 95.8g.
5% Fiducial limits = ± 195.6g.

The DT:LP routine apparently had a marked effect on reducing leg weight. All the low plane groups except MT:LP are significantly lighter than the C:NP group.

Dissection work confirmed that it was difference in weight of leg muscular tissue which produced differences in leg weight between the treatment groups.

Table 24

Weight of dissectible muscle (g.) in the leg. Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	1839.6	132.6			
C:NP	1864.4	124.1	C:LP	1662.6	163.5
LT:NP	1737.2	100.9	LT:LP	1543.0	72.8
MT:NP	1728.8	128.3	MT:LP	1614.2	94.3
HT:NP	1794.2	179.9	HT:LP	1685.4	106.4
			DT:LP	1354.8(4)	52.3(4)

Table 25

Analysis of variance of weight of dissectible muscle (g.) in the leg.

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	99611	33204	2.098	ns
Plane of nutrition	1	239785	239785	15.150	ss
Treatment interaction	3	18733	6244	0.395	ns
Within subclass	32	506471	15827		
Total	39	864600			

Standard error of the treatment means = 56.25g.
5% Fiducial limits = ± 114.9g.
1% Fiducial limits = ± 154.7g.

Table 24 shows that the low plane of nutrition appears to have reduced muscle weight, with less effect at the higher levels of thyroxine implantation. Implanted thyroxine appears to have reduced muscle weight on the normal plane of nutrition but has had no effect per se on the low plane. The more severe daily thyroxine treatment has caused a highly significant further reduction in weight of leg muscle on the low plane.

It can be seen from Table 26 that the only treatment which appears to have lowered the weight of dissected fat in the leg is daily thyroxine on a low plane of nutrition.

Table 26

Weight of dissectible fat (g.) in the leg. Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	776.2	111.6			
C:NP	766.2	193.1	C:LP	703.0	143.6
LT:NP	737.8	143.1	LT:LP	698.4	156.4
MT:NP	795.0	103.8	MT:LP	831.8	191.0
HT:NP	715.8	96.5	HT:LP	764.4	91.3
			DT:LP	396.5(4)	70.42(4)

The group means in Table 27 suggest no treatment effects upon the weight of bone in the leg joint.

Table 27

Weight of dissectible bone (g.) in the leg. Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	299.0	28.3			
C:NP	291.5	24.4	C:LP	293.3	22.1
LT:NP	307.9	13.2	LT:LP	283.3	10.7
MT:NP	277.2	21.3	MT:LP	294.1	25.4
HT:NP	309.6	36.2	HT:LP	300.5	24.9
			DT:LP	297.5(4)	36.4(4)

(2) Half loin

Statistical analysis of this joint reveals an almost significant effect of thyroxine treatment. The low proportion of muscle in this cut in comparison to the leg is likely to be the reason for a lack of nutritional effect.

Table 28

Weight of the half loin cut (g.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	1779	334			
C:NP	1777	461	C:LP	1490	381
LT:NP	1505	231	LT:LP	1241	275
MT:NP	1651	290	MT:LP	1651	278
HT:NP	1327	267	HT:LP	1373	155
			DT:LP	1362(3)	452(3)

Table 29

Analysis of variance of the weight of the half loin cut (g.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	792909	264303	2.847	almost s
Plane of nutrition	1	159391	159391	1.717	ns
Treatment interaction	3	227121	75707	0.815	ns
Within subclass	32	2971134	92848		
Total	39	4150555			

Standard error of the treatment means = 136.3g.
5% Fiducial limits = $\pm$ 278.3g.

It can be seen that the significance lies between the C:NP group and some of the thyroxine treated groups. The C:LP is also significantly lighter than the C:NP group. That this is a real and not a chance effect is suggested by the fact that all of the thyroxine and the low plane groups have a lower mean half loin weight than those of the CB. or C:NP groups. Apparently the short duration of the experimental period and high variability of the data prevented more groups from showing a significant treatment weight loss.

An analysis of variance showed highly significant treatment effects on the weight

of muscle in the half loin.

Table 30

Weight of dissectible muscle (g.) in the half loin. Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	722.2	85.0			
C:NP	798.6	67.8	C:LP	655.8	116.4
LT:NP	690.0	83.2	LT:LP	584.2	63.7
MT:NP	605.8	84.1	MT:LP	593.0	79.3
HT:NP	657.8	100.5	HT:LP	560.6	37.8
			DT:LP	617.3(3)	133.6(3)

Table 31

Analysis of variance of weight of dissectible muscle (g.) in the half loin.

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	101677	33892	5.019	ss
Plane of nutrition	1	80371	80371	11.902	ss
Treatment interaction	3	22621	7540	1.117	ns
Within subclass	32	216108	6753		
Total	39	420777			

Standard error of the treatment means = 36.75g.
5% Fiducial limits = $\pm$ 75.0g.
1% Fiducial limits = $\pm$ 101.1g.

Reference to Table 30 suggests that a low plane of nutrition has in all cases reduced the weight of muscle in the half loin cut. Thyroxine has caused without exception, a reduction of muscle weight on the normal plane ewes, but in only one case in the low plane groups is the reduction significant. Once again no differences can be attributed to the different levels of thyroxine implantation, and the DT:LP group appears to be no more effected than any of the other thyroxine treated groups.

The weight of fat in the half loin cut is unaffected by the two treatments as is shown in Table 33.

Table 32

Weight of dissectible fat (g.) in the half loin. Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	858.8	296.7			
C:NP	778.6	429.7	C:LP	642.6	261.9
LT:NP	631.2	118.3	LT:LP	516.8	146.2
MT:NP	849.8	201.6	MT:LP	790.8	312.2
HT:NP	549.0	175.3	HT:LP	646.8	103.3
			DT:LP	522.0(3)	320.5(3)

Table 33

Analysis of variance of weight of dissectible fat (g.) in the half loin cut.

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	385229	128410	2.083	ns
Plane of nutrition	1	27984	27984	0.454	ns
Treatment interaction	3	83589	27863	0.452	ns
Within subclass	32	1973150	61661		
Total	39	2469952			

The great variability in the weight of fat in this joint, as in other regions of the carcass and in the carcass as a whole, means that large differences are required to achieve statistical significance. However, as significance is approached for the effects of thyroxine on the dissected fat in the half loin, and as thyroxine caused a highly significant reduction in the weight of muscle in the half loin, these two factors together are responsible for the almost significant reduction in the total weight of this cut.

(3) The 9-10-11 rib cut

It was possible to add chemical data where this would help in the interpretation of the results for this cut because it was analysed physically for the left half carcass and chemically for the right half carcass.

The treatments produced no demonstrable effects on the total weight of the rib cut. However, the mean weight of the rib cut in the DT:LP group does suggest that

this extreme treatment combination may have started to lighten this region of the carcass.

Table 34

Weight of the rib cut (g.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	1253.0	227.8			
C:NP	1079.8	237.6	C:LP	948.8	134.2
LT:NP	989.6	100.6	LT:LP	903.0	236.0
MT:NP	1096.2	135.2	MT:LP	1054.8	277.6
HT:NP	858.4	140.3	HT:LP	929.4	110.7
			DT:LP	773.7(3)	243.6(3)

Table 35

Analysis of variance of the weight of the rib cut (g.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	188256	62752	1.876	ns
Plane of nutrition	1	22090	22090	0.661	ns
Treatment interaction	3	56399	18800	0.562	ns
Within subclass	32	1070207	33444		
Total	39	1336952			

The muscular tissue has comparatively low variability and shows highly significant treatment effects.

Table 36

Weight of dissectible muscle in the rib cut (g.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	409.8	36.3			
C:NP	402.6	34.3	C:LP	330.2	38.9
LT:NP	338.2	15.4	LT:LP	309.8	18.6
MT:NP	329.8	20.9	MT:LP	292.4	29.6
HT:NP	331.6	15.9	HT:LP	305.8	30.6
			DT:LP	271.3(3)	42.0(3)

Table 37

Analysis of variance of weight of dissectible muscle (g.) in the rib cut.

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	18459	6153	8.534	ss
Plane of nutrition	1	16810	16810	23.315	ss
Treatment interaction	3	3471	1157	1.605	ns
Within subclass	32	23084	721		
Total	39	61824			

Standard error of the treatment means = 12.01g.
5% Fiducial limits = ± 24.5g.
1% Fiducial limits = ± 33.0g.

It can be seen from Table 36 that the plane of nutrition effect of lowering the weight of muscular tissue is present between the controls and at all levels of thyroxine treatment. Thyroxine has reduced the weight of muscle on both planes of nutrition, with much larger effects on the normal plane. No differences are attributable to the levels of thyroxine implantation, and the DT:LP treatment has proved more severe than the implantation treatments.

As chemical data were available on the rib cut it was of interest to see if this muscle loss was a protein loss, or whether it was a dehydration effect.

Table 38

Weight of protein (g.) in the rib cut. Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	117.8	16.7			
C:NP	109.7	11.1	C:LP	103.2	9.4
LT:NP	106.8	4.6	LT:LP	100.5	11.4
MT:NP	107.3	2.5	MT:LP	101.2	1.2
HT:NP	104.8	14.0	HT:LP	105.1	15.7
			DT:LP	96.2(3)	14.1(3)

Table 39

Analysis of variance of weight of protein (g.) in the rib cut.

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	43.7	14.5	0.14	ns
Plane of nutrition	1	213.0	213.0	2.08	ns
Treatment interaction	3	83.0	27.7	0.27	ns
Within subclass	32	3273.0	102.3		
Total	39	3612.7			

Table 40

Weight of water (g.) in the rib cut. Means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	392.5	46.9			
C:NP	410.6	44.3	C:LP	344.5	18.9
LT:NP	380.8	33.5	LT:LP	313.7	44.0
MT:NP	340.4	18.6	MT:LP	305.7	22.5
HT:NP	328.6	16.7	HT:LP	314.7	33.7
			DT:LP	286.9(3)	41.5(3)

Table 41

Analysis of variance of weight of water (g.) in the rib cut.

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	24474	8158	8.54	ss
Plane of nutrition	1	9266	9266	9.70	ss
Treatment interaction	3	5281	1760	1.84	ns
Within subclass	32	30581	956		
Total	39	69602			

Standard error of the treatment means = 13.82g.
5% Fiducial limits = $\pm$ 28.22g.
1% Fiducial limits = $\pm$ 38.00g.

Statistical analyses revealed no treatment effects upon the weight of protein in the rib cut but highly significant effects upon the weight of water. It can be seen by comparing Table 36 with Table 40 that in general the weight of water reflects very well the treatment effects on weight of muscle. The thyroxine effects show up equally well in both tables, but the plane of nutrition has less severe effects upon weight of water in the rib cut.

Further results of a preliminary nature confirm that the loss of water is due to muscle dehydration. The average water percentage in the fat free rib muscle tissue

(uncorrected) is 77.5 for the C:NP and 76.8 for the C:LP, with an average for both groups of control sheep of 77.2%. The comparable figure for the 30 thyroxine implanted sheep is 75.6% water in the rib muscle on a fat free basis (uncorrected), indicating muscle dehydration in these latter ewes. The control value of 77.2% water agrees with the value of 77% water in the fat free boneless meat of stored frozen carcasses postulated by Callow (1947).

Preliminary observations failed to reveal dehydration in the rib fatty tissue of the thyroxine implanted ewes. For fatty tissue of the rib cut, the percentage water on a fat free basis (uncorrected) averaged 80.6 for the C:NP and C:LP ewes, and 80.3 for the LT:NP and LT:LP ewes, indicating no dehydration of the fatty tissue in this region of these implanted ewes.

In Table 42 are presented the average weights of the dissectible fat from the rib cuts.

Table 42

The weight of dissectible fat (g.) of the rib cut. Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	683.6	199.5			
C:NP	510.8	201.8	C:LP	468.8	126.7
LT:NP	497.2	86.1	LT:LP	460.8	199.2
MT:NP	625.6	124.8	MT:LP	624.4	264.5
HT:NP	401.4	137.8	HT:LP	504.0	109.1
			DT:LP	391.0(3)	229.3(3)

This table demonstrates the high variability of dissected fat in the rib cut. It appears that the treatments may have been starting to take effect in the DT:LP group.

(4) Perirenal fat

An analysis of variance showed no significant treatment effects on the weight of the perirenal fat from the left half carcass.

Table 43

Weight of perirenal fat (g.) from left half carcass. Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	681.2	216.5			
C:NP	573.0	206.7	C:LP	443.4	89.4
LT:NP	546.2	324.6	LT:LP	392.0	123.5
MT:NP	488.2	158.9	MT:LP	544.8	184.0
HT:NP	294.2	143.4	HT:LP	498.6	203.7
			DT:LP	323.7(3)	195.3(3)

Table 44

Analysis of variance of weight of perirenal fat (g.) from the left half carcass.

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	90133	30044	0.82	ns
Plane of nutrition	1	325	325	-	ns
Treatment interaction	3	213566	71189	1.94	ns
Within subclass	32	1176142	36754		
Total	39	1480166			

The variability of weight of perirenal fat within each group is high. This is in agreement with the situation found for other fats already discussed.

(E) RESIDUAL IODINE DETERMINATIONS

Microchemical analyses of the bulked group mince tissue gave the following results for the following groups:-

High thyroxine, normal plane = 1.2µg. I_2 / g. mince
Low thyroxine, normal plane = 0.18µg. I_2 / g. mince
Control, normal plane = 0.18µg. I_2 / g. mince.

The individual samples of mince from the HT:NP group were then analysed to see if all samples were contributing to the high mean value of this group.

HT:NP group	Residual iodine in µg./g. of mince
Ewe 8	0.087
Ewe 28	0.150
Ewe 314	0.087
Ewe 538	0.087
Ewe 551	2.50 (approx.)

It can be seen that the main factor contributing to the comparatively high residual iodine level in the HT:NP group is the high level for ewe 551. Apart from the remote possibility that the mince sample came from a region adjacent to a removed implant residue, a reason for this high value cannot be advanced on the limited data available.

DISCUSSION

In view of the highly significant effects of the treatments on the liveweights of the ewes, it was surprising that no differences could be detected statistically between the group mean carcass weights. The DT:LP group, not included in the analysis of variance, does appear to have had its average carcass weight lowered. Because the remaining group means for carcass weight are all below the CB. and C:NP means, this suggests that there may have been treatment effects. However, these could not be demonstrated because of the high variability of these data.

This result demonstrates clearly, the dangers involved in taking liveweight as a criterion for experimental effects.

The mean hot carcass weight for this series was 61.8 lb. (range 43.1 - 78.8 lb.) which is only 5 lb. above the New Zealand 10 year average from 1946-47 to 1955-56 seasons. Reference to Table 2, from Smith-Filling and Barton (1954), would also suggest that these are not an extreme group of carcasses.

However, the reason for the lack of significant treatment effects on carcass weight was made obvious by the data on complete or regional carcass fat weights. The high variability of carcass weight is reflected in an equally high variability for carcass fat, and fat in these series is one of the main components of carcass weight. In no case can statistically significant treatment effects be shown on carcass fat or on fat from the cuts. This applies to both the chemical and physical fat weights. Furthermore, there are no treatment effects on perirenal fat.

The only exception where treatment effects may be present is the DT:LP group

which was not analysed statistically.

It was noted that two C:NP carcasses had comparatively low fat percentages at the completion of the experimental period. This could be due to chance in the random allocation of sheep to the experimental groups, whereby two particularly lean ewes were allocated to this group. In this connection also, the chance allocation of two ewes of over 50% chemical carcass fat to the MT:LP group may have prevented the demonstration of statistically significant treatment effects on carcass fat.

However, the overall results suggest that surplus fat cannot be removed from ewe carcasses in a relatively short period of time without endangering the lives of these animals.

The average total carcass fat percentage was 40.4 (range 24.9% - 54.3%) which does highlight the problem involved in this country, as these ewes were not an extreme group of animals, and are representative of a large proportion of the old ewes sold to the meat works.

In contrast to the lack of treatment effects on carcass fat, is the marked treatment effects and low variability of the "chemical fat" free carcass weight. This could account for from 4 - 10 lb. of the liveweight loss. It was possible to partition the fat free carcass into its components. Likewise, the weight of physically determined muscular tissue is also indicative of treatment effects on protein and water.

A low plane of nutrition caused a highly significant loss of protein, which was associated with a loss of water. This was suggestive of a loss of muscular tissue, which was confirmed statistically by analysis of the estimated total weight of dissected carcass muscular tissue. The low plane ewes (excluding DT:LP) showed a loss of 9% of carcass protein when compared with the normal plane ewes. Thyroxine, on the other hand, has caused a dehydration of the fat free carcass as indicated by the lowering of the proportion of water in the fat free carcass; this proportion has been regarded by many workers as a "biological constant" under normal conditions. The normal plane,

thyroxine implanted sheep had their weight of carcass water reduced by 18.4% as compared to the C:NP group. On the other hand, the low plane implanted sheep had the weight of carcass water reduced by 3.9% when compared to the C:LP sheep.

Some preliminary analyses of the rib cut indicate that dehydration of the muscular tissue occurred in the thyroxine treated sheep. Dehydration, however, was not detected in some preliminary analyses of the fatty tissue of this cut. Both dehydration and loss of muscular tissue will account for carcass water loss.

The observation that muscular tissue (and protein) had been reduced by undernutrition is in line with the observations of Keys et al (1950). Because of this muscle loss, it is surprising to note that the fatty tissue of the carcass (and chemical fat) has not been reduced, particularly in view of the evidence reviewed which indicates that when body weight is lost, fatty tissue is usually the first tissue removed. Reported experiments suggest that there is usually a proportionately larger reduction of body and carcass fat than of body weight, in contrast to the other tissues of the body. However, as mentioned earlier, it is possible that the chance variations of the initial carcass fat percentages in the experimental groups, and the overall variability of this component, prevented statistical significance from being reached.

The above results in general apply also to the specific regions of the carcass examined. The leg and loin weights both showed treatment effects.

The reduction in leg weight of the low plane sheep (excluding DT:LP) is in the order of 8% when compared with the C:NP sheep. When compared on the same basis, the leg weights of four DT:LP sheep (owing to the experimentally induced death, this joint was not available for the fifth ewe) were reduced by 29%. For muscular tissue the reduction is in the order of 13% and 29% respectively for the low plane ewes mentioned above and the DT:LP ewes when compared with the weight of muscular tissue of the C:NP ewes.

The low proportion of fatty tissue and high proportion of muscular tissue in the leg, as compared to the other two cuts examined, is likely to be the explanation of the

statistically significant low plane reduction in leg weight.

On the other hand, the almost significant reduction in loin weight is attributable to thyroxine treatment. The thyroxine-caused reduction of loin muscle is supported by a tendency in the same direction for the fatty tissue in the thyroxine treated animals, giving an overall thyroxine treatment reduction in loin weight. The low plane of nutrition has only reduced the weight of loin muscle which was not sufficient to effect the total loin weight. As compared with the NP. sheep, the LP. sheep (excluding DT:LP) lost 13% of loin muscular tissue. The normal plane implanted sheep lost 18% of muscular tissue as compared with the C:NP, while the low plane implanted sheep lost 12% as compared with C:LP.

The weight of the rib cut showed no treatment effects and this also applied to the fatty tissue of this cut. However, the muscular tissue responded to both treatments as did the loin muscle. It was, therefore, unexpected that no treatment effects could be shown on the weight of protein in the rib cut. However, this result can be explained by the fact that both treatments had lowered the weight of water in the rib cut.

Throughout these results it should be noted that there has been no consistent difference between the three levels of thyroxine implantation. In general the DT:LP treatment has produced greater weight reductions than thyroxine implantation. This supports the evidence on liveweight which suggested that the daily rate of uptake of thyroxine from the implants must have been less than 5mg. l-thyroxine per day. Thyroxine implantation, where effective, produced less weight loss on the low plane of nutrition than on the high plane. This effect is consistent with that demonstrated earlier on liveweight.

It is now appropriate to compare the different sample joints. The normal abbreviations to denote statistical significance levels are used:-

Treatment effects on chemical fat and fatty tissue weight

Treatment	Chemical fat	Fatty tissue			
	Carcass	Carcass+	Leg+	Loin	Rib+
Thyroxine	ns	No effects	No effects	ns	No effects
Plane of nutrition	ns	No effects	No effects	ns	No effects

+Because of the similarity of the group means of fatty tissue and wide variability, no analysis of variance was carried out.

Treatment effects on muscular tissue weight

Treatment	Carcass+	Sample joint		
		Leg	Loin	Rib cut
Thyroxine	s	ns	ss	ss
Plane of nutrition	ss	ss	ss	ss

+ Estimated from leg+loin.

Treatment effects on protein and water weights

Treatment	Protein		Water	
	Carcass	Rib cut	Carcass	Rib cut
Thyroxine	ns	ns	ss	ss
Plane of nutrition	ss	ns	ss	ss

For all joints and for the carcass as a whole no treatment effects were demonstrated on weight of fat.

It can be seen that the significant effect of thyroxine on the weight of carcass muscle is made up of a non-significant effect on the leg and a highly significant effect on the loin. Thus, used individually, these joints would have given different answers concerning the effects of thyroxine on the weight of muscle in the carcass. The rib cut gives the same results as the loin. The plane of nutrition effect on muscle was shown on all joints.

From the chemical analyses, the rib cut indicated treatment effects on water weight but failed to reveal a reduction of protein on a low plane of nutrition, which had been detected in the carcass as a whole. This difference is probably explicable in terms of the large differences in weight of the rib cut and the small variability

in the percent of protein in this cut, which meant that the weight of protein to a large extent reflected the weight of the rib cut upon which no treatment effects could be demonstrated.

The usefulness of sample joints and their relationship to the carcass as a whole will be further discussed in PART II. They have revealed differential treatment responses for different parts of the carcass, and as is to be expected with samples, do not give as much information as does complete carcass analysis.

It should be noted that the figure of 71.9% water in the fat free ewe carcass, is in excellent agreement with the value of 72 - 73% postulated by many other workers, (Murray, 1922; Pace and Rathbun, 1945; Babineau and Pagé, 1955) as a "biological constant" for the carcasses of cattle, guinea pigs and rats respectively. As the chemical analyses in the present experiment were done on stored carcasses, the values for fresh carcasses should be within the above range if shrinkage losses are taken into account. This experiment has demonstrated that thyroxine but not plane of nutrition has caused a reduction of the proportion of water in the fat free carcass.

The observation that the percentage water on a fat free basis is uncorrelated with both percentage and weight of fat in the carcasses of these ewes is in agreement with a similar observation by Babineau and Pagé (1955) on rats. These above results suggest that if the "constant" of carcass water may be taken as synonymous with body water, as has been done by many workers, then body water is a good indicator of body fat, completely independently of the quantity of body fat, c.f. Keys and Brožek (1953).

Preliminary results on the control ewes show that 77% of the fat free rib muscle weight can be attributed to water which is in agreement with Callow's (1947) results from stored frozen carcasses.

Microchemical iodine determinations of the levels of thyroxine from the carcasses of the two implanted groups studied, indicate that the meat is safe for human consumption. Care must, however, be taken to see that no implants are left on the surface of the carcass. In most cases the implants were removed with the skin.

The bandsaw technique is the first reported method which enables chemical analyses to be carried out on complete large animal carcasses. By using this method, total chemical carcass fat can be obtained, which is of particular value for specific gravity purposes, or any studies related to stored energy in the carcasses such as those on efficiency or nutrition. Such studies are concerned more with chemical than with dissectible fat since dissectible fat contains varying proportions of chemical fat.

Furthermore, it is possible to obtain information using the bandsaw technique, including the chemical work involved, in approximately 3 man-hours per carcass as opposed to the estimated 72 - 84 man-hours (Pálsson, 1939) required to completely dissect out a carcass. The low standard errors of the mean and coefficients of variation for the uncorrected percentages water, chemical fat and dried fat free residue respectively, suggest that the sampling technique is sound.

The chemical methods used in this experiment differ from those reported by other workers. in being macrochemical as compared to the standard chemical procedures. That is, 300g. of mince divided into 50g. samples are analysed per carcass and an accuracy of weighing of $\pm$ 0.5g. would give chemical accuracy of $\pm$ 1%. It is considered that greater accuracy than this was achieved.

Normal Soxhlet and Kjeldahl methods for fat and protein determination respectively, would limit both size of sample, and the number of samples it would be practical to analyse. It is considered that the increased accuracy of sampling made possible by the present methods of sampling and size of sample more than offsets the slightly reduced accuracy of the present chemical methods as compared to the standard ones. It may be noted that the above methods give the same answers for such " biological constants" as percentage water in the fat free carcass and percentage water in the fat free muscular tissue as have been obtained using the standard methods.

CHAPTER VI

TREATMENT EFFECTS UPON WEIGHT OF GASTROINTESTINAL CONTENTS AND WEIGHT OF TRACT

RESULTS

Table 46 presents the statistical analysis of treatment effects upon the weight of contents of the gastrointestinal tract. In ruminants these contents (fill) are one of the major sources of variation of body weight.

Table 45

Weight of gastrointestinal contents (lb.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	9.1	1.55			
C:NP	12.3	2.11	C:LP	11.0	2.79
LT:NP	9.0+	2.85	LT:LP	8.3	1.18
MT:NP	8.2	2.92	MT:LP	7.3	1.35
HT:NP	11.3	3.15	HT:LP	7.1	1.92
			DT:LP	7.7(3)	1.29(3)

+Underestimate. Some loss of gastric contents occurred from one ewe.

Table 46

Analysis of variance of weight (lb.) of the gastrointestinal contents.

Source	d.f.	S.S.	M.S.	F.	
Thyroxine treatment	5	84.727	28.242	4.945	ss
Plane of nutrition	1	30.800	30.800	5.393	s
Treatment interaction	5	20.808	6.956	1.214	ns
Within subclass	52	182.750			
Total	59	319.085			

Standard error of the treatment means = 1.069 lb.
5% Fiducial limits = ± 2.18 lb.
1% Fiducial limits = ± 2.94 lb.

Firstly, it should be noted in Table 45 that the CB. group is not comparable to the other experimental groups owing to the different management these animals received just prior to slaughter. Secondly, it should be noted that the NP. ewes were starved prior to slaughter for approximately 23 hours, as compared with approximately 41 hours for the LP. ewes. This factor alone should be enough to account for the plane of

nutrition effect shown in Table 46. In view of the nature of the low plane treatment and the effects this has had on reducing liveweight, it is surprising that the reduction of the gastrointestinal contents of the low plane sheep was not greater. The thyroxine treatment has produced a marked decrease of gastrointestinal contents in all groups except the HT:NP, when compared to the controls.

As the information was available, it was decided to analyse the weights of the contents of the stomachs, and of the intestines separately, to see if the weights of both had been reduced.

Table 47

Weight of gastric contents (mainly ruminal) (lb.) Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	6.5	1.65			
C:NP	8.4	2.13	C:LP	8.0	2.46
LT:NP	6.3+	2.31	LT:LP	5.8	0.85
MT:NP	6.0	2.33	MT:LP	4.9	0.98
HT:NP	8.9	2.98	HT:LP	4.7	1.20
			DT:LP	4.4(3)	0.77(3)

+Underestimate. A small loss of gastric contents occurred from one ewe.

Table 48

Analysis of variance of weight of gastric contents (mainly ruminal) (lb.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	42.051	14.010	3.355	s
Plane of nutrition	1	22.350	22.350	5.352	s
Treatment interaction	3	20.686	6.895	1.651	ns
Within subclass	52	133.630	4.176		
Total	59	218.697			

Standard error of the treatment means = 0.914 lb.
5% Fiducial limits = ± 1.87 lb.

Table 49

Weight of intestinal contents (lb.) Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	2.65	0.77			
C:NP	3.85	0.54	C:LP	3.07	0.72
LT:NP	2.70	0.89	LT:LP	2.45	0.53
MT:NP	2.15	0.72	MT:LP	2.45	0.62
HT:NP	2.66	0.56	HT:LP	2.37	0.83
			DT:LP	3.32(3)	0.57

Table 50

Analysis of variance of weight of intestinal contents (lb.)

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	7.952	2.651	5.90	ss
Plane of nutrition	1	0.676	0.676	1.51	ns
Treatment interaction	3	1.407	0.469	1.04	ns
Within subclass	32	14.366	0.449		
Total	39	24.401			

Standard error of the treatment means = 0.300 lb.
5% Fiducial limits = $\pm$ 0.61 lb.
1% Fiducial limits = $\pm$ 0.82 lb.

As mentioned previously, the CB. group is not comparable to the remaining groups. The plane of nutrition effect would appear likely to be a storage effect of the rumen and it may be observed that this only reaches significance between the two high thyroxine implanted groups. All implanted groups except HT:NP have a significantly lighterweight of gastric contents than their appropriate controls. The reduction of weight of intestinal contents is highly significant for the implanted sheep on the high plane of nutrition, and is only significant on the low plane. Balch et al. (1952) presented evidence which suggested that thyroxine speeds up the passage of food through the rumeno-reticulum. In view of this, the reduced weight of intestinal contents in the thyroxine implanted sheep is likely to indicate a more rapid passage of food through the intestines. The presence of fresh dags on the high plane implanted sheep supports this interpretation.

The comparatively high weight of intestinal contents of the DT:LP ewes has probably resulted from the greatly reduced frequency of thyroxine injection over the latter part of the experimental period.

The weight of the empty gastrointestinal tract was statistically analysed to see if it would help to explain the treatment effects on the weight of contents.

Table 51

Weight of gastrointestinal tract (lb.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	7.80	0.85			
C:NP	8.62	0.86	C:LP	6.22	0.99
LT:NP	7.54	0.87	LT:LP	6.38	0.77
MT:NP	6.88	0.70	MT:LP	5.61	0.35
HT:NP	7.47	0.42	HT:LP	5.93	0.50
			DT:LP	5.65(3)	0.49(3)

Table 52

Analysis of variance of weight of gastrointestinal tract (lb.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	7.241	2.414	4.716	ss
Plane of nutrition	1	25.361	25.361	49.552	ss
Treatment interaction	3	2.365	0.788	1.540	ns
Within subclass	32	16.377	0.512		
Total	39	51.344			

Standard error of the treatment means = 0.320 lb.
5% Fiducial limits = $\pm$ 0.653 lb.
1% Fiducial limits = $\pm$ 0.880 lb.

By comparing Table 45 with Table 51 it can be seen that the treatment effects on the weight of the gastrointestinal tract and contents can account for at least 8 lb. of the loss in liveweight, c.f. MT:LP versus C:NP. The decrease of gastrointestinal contents makes up the larger fraction of this overall loss. As highly significant treatment effects were produced on the weight of gastrointestinal tract, it was subdivided into gastric weight and intestinal weight and reanalysed.

Table 53

Gastric weight (lb.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	3.98	0.37			
C:NP	4.58	0.50	C:LP	3.22	0.52
LT:NP	3.65	0.71	LT:LP	3.06	0.26
MT:NP	3.38	0.31	MT:LP	2.76	0.19
HT:NP	3.59	0.31	HT:LP	3.01	0.35
			DT:LP	2.77(3)	0.23(3)

Table 54

Analysis of variance of gastric weight (lb.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	5	5.708	1.256	6.91	ss
Plane of nutrition	1	6.202	6.202	34.68	ss
Treatment interaction	5	1.095	0.365	2.04	ns
Within subclass	52	5.722	1.079		
Total	59	16.727			

Standard error of the treatment means = 0.189 lb.
5% Fiducial limits = $\pm$ 0.586 lb.
1% Fiducial limits = $\pm$ 0.520 lb.

Table 55

Intestinal weight (lb.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	3.82	0.59			
C:NP	4.04	0.42	C:LP	3.00	0.47
LT:NP	3.89	0.25	LT:LP	3.32	0.70
MT:NP	3.50	0.41	MT:LP	2.85	0.25
HT:NP	3.88	0.16	HT:LP	2.92	0.28
			DT:LP	2.88(3)	0.28(3)

Table 56

Analysis of variance of intestinal weight (lb.)

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	5	1.046	0.349	2.18	ns
Plane of nutrition	1	6.480	6.480	40.50	ss
Treatment interaction	5	0.596	0.132	0.83	ns
Within subclass	52	5.108	0.160		
Total	59	13.030			

Standard error of the treatment means = 0.179 lb.
5% Fiducial limits = $\pm$ 0.365 lb.
1% Fiducial limits = $\pm$ 0.492 lb.

It must once again be emphasized that the CB. group is not comparable to the remaining groups for the reasons given earlier.

The above tables reveal that the low plane of nutrition has had marked effects upon both regions of the digestive tract, while the thyroxine treatment has only

reduced the gastric weight. The latter effect is most marked on the normal plane of nutrition. When compared with the C:NP group, the mean weight of the stomaches of the MT:LP (most effected group) have been reduced by approximately 40% which indicates the severity of the treatment effects.

The weight of the gastric contents reflect treatment effects on gastric weight whereas the treatment effects on intestinal contents are in marked contrast to effects on intestinal weight. Correlations were calculated between the above variables to aid in interpretation of results.

(1) Correlations between gastric contents and gastric weight (empty)

Experimental animals	Correlation	
Total 48 ewes	r = +0.4264	ss
33 Thyroxine treated ewes	r = +0.4985	ss
15 Control ewes	r = +0.0216	ns

The hypothesis that the two sample values of r(for the latter two correlations) were drawn at random from the same population was tested according to Snedecor (1946, p.151).

Lot	Sheep in lot	r	z	$\frac{1}{n-3}$
Thyroxine treated	33	0.4985	0.546	0.0333
Controls	15	0.0216	0.022	0.0833
		Difference	0.524	Sum 0.1166
S_d = 0.3415	t = 1.532	d.f. = ∞	p = 0.13	ns

With p = 0.13 there was no reason to reject the hypothesis that the r's are from a common population correlation.

(2) Correlations between intestinal contents and intestinal weight (empty).

Experimental animals	Correlation	
Total 48 ewes	r = +0.3289	s
33 Thyroxine treated ewes	r = +0.2773	ns
15 Control ewes	r = +0.2622	ns

(3) Correlations between gastric weight (empty) and intestinal weight (empty).

Experimental animals	Correlation	
Total 48 ewes	r = +0.7582	ss
33 Thyroxine treated ewes	r = +0.8345	ss
15 Control ewes	r = +0.6898	ss

The above correlations are likely to consist of a biological relationship between the two organs, i.e. the animals with a greater gastric weight also have a greater intestinal weight.

(4) Correlations between gastric contents and intestinal contents

Experimental animals	Correlation	
Total 48 ewes	r = +0.3968	ss
33 Thyroxine treated ewes	r = +0.3318	ns
15 Control ewes	r = +0.2398	ns

DISCUSSION

The results from this experiment have demonstrated that hyperthyroidism has lowered the weight of the gastrointestinal contents in the ewe. Group mean losses of up to 4 lb. liveweight could be attributed to this cause. Thyroxine implantation lowered the weight of both the gastric (mainly ruminal) and intestinal contents. This is in contrast to hypothyroidism, which Frens (1949) demonstrated to cause an increase in the weight of ruminal contents in cattle.

It is possible that a lowered intake may partly explain the lowered weight of gastrointestinal contents recorded. However, no differences were observed between the grazing behaviour of the control animals and the thyroxine treated animals on either plane of nutrition. The low plane animals all appeared to fully utilise their restricted grazing period. Also, it should be noted that the literature suggests that thyroxine normally increases intake except in extreme cases of hyperthyroidism, such as was noted on the two DT:LP ewes which did not survive the experimental period. It is therefore considered that lowered intake is unlikely to be the explanation for

the lowered weight of gastrointestinal contents.

Balch et al. (1952) presented evidence which suggested that thyroxine speeds up the passage of food through the rumeno-reticulum (in cattle). If this also occurs in the ewe, it could explain the reduction of the mean weight of the gastric contents in this present experiment. As thyroxine reduced both empty gastric weight and the weight of gastric contents, the lowered empty gastric weight in the thyroxine treated sheep may also help to explain some of the loss of contents.

Balch's (1952) evidence cannot, however, explain the reduced weight of intestinal contents, which supports the hypothesis put forward by Blaxter (1948), that thyroxine speeds up the passage of food through the digestive tract. The formation of fresh dags by some of the thyroxine implanted normal plane ewes in this present experiment, and the thyroxine induced scouring observed by Blaxter et al. (1949) in cattle, support this hypothesis.

It may be noted that thyroxine therapy caused a highly significant reduction in weight of the intestinal contents, in contrast to the lack of thyroxine effect and a highly significant low plane reduction in weight of the intestines themselves. The first noted is probably a physiological response while the latter is a morphological response.

The above results should be considered in relation to Balch's (1952) conclusion that thyroxine did not measurably increase the rate of passage of food through the digestive tract of hyperthyroid cattle. In the present experiment, the weight of intestinal contents were reduced on the average in the normal plane ewes by slightly over 1 lb. in 28 days. In the low plane ewes the reduction was even less. It would not need a large increase in the rate of passage of food through the intestines to produce such differences, and so the present findings do not necessarily contradict those of Balch et al. (1952).

The almost complete absence of ruminal contents in the two DT:LP ewes which did not survive the experimental period, as mentioned earlier, is suggestive of self-imposed starvation. This has been observed in cases of extreme hyperthyroidism in wethers by Blaxter (1948).

The low plane of nutrition caused a highly significant reduction in both gastric and intestinal weight, which agrees with reported observations. For the C:LP ewes, this reduction was in the order of 30% and 26% for gastric and intestinal weight respectively, as compared with the C:NP ewes. The most extreme weight losses occurred in the MT:LP group where the mean reduction in gastric and intestinal weight was 40% and 29% respectively when compared to the C:NP group.

The group mean losses of weight of gastrointestinal tract could account for up to 2 lb. of liveweight in the normal plane thyroxine implanted ewes. Thus the total loss of weight of tract and contents, attributable to thyroxine implantation, on a normal plane of nutrition, could account for a group mean loss of liveweight of up to 6 lb. This should be considered in relation to the average loss of liveweight from thyroxine implanted ewes of 10 lb. reported by Hart (1955).

CHAPTER VII

TREATMENT EFFECTS ON WEIGHTS OF INTERNAL FAT DEPOTS AND SELECTED ORGANS

RESULTS

(A) INTERNAL FAT DEPOTS

(1) Omental Fat

Before doing an analysis of variance on the omental fat data, Bartlett's test of homogeneity of variance was applied. This test gave a χ^2 of 11.598 for 9 d.f., which gives a $p > 50\%$, indicating that the hypothesis of equality of the variances is acceptable.

Table 57

Weight of omental fat (lb.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	5.26	1.13			
C:NP	4.42	2.06	C:LP	3.81	1.12
LT:LP	4.20	0.60	LT:LP	3.41	0.95
MT:NP	3.94	0.75	MT:LP	3.58	1.14
HT:NP	3.37	1.82	HT:LP	3.33	0.76
			DT:LP	2.45(3)	0.75(3)

Table 58

Analysis of variance of weight of omental fat (lb.)

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	2.9612	0.987	0.63	ns
Plane of nutrition	1	2.0250	2.025	1.29	ns
Treatment interaction	3	0.7935	0.265	0.17	ns
Within subclass	32	50.0980	1.566		
Total	39	55.8777			

Although no significant treatment effects were shown on omental fat, it should be noted that the remaining group means are all less than the CB. and C:NP group means which suggests that the treatments may have been starting to produce effects.

(2) Mesenteric Fat

The data on mesenteric fat weight showed no significant treatment effects.

Table 59

Weight of mesenteric fat (lb.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	1.87	0.54			
C:NP	1.93	0.41	C:LP	1.48	0.42
LT:NP	1.65	0.27	LT:LP	1.53	0.55
MT:NP	1.45	0.16	MT:LP	1.60	0.37
HT:NP	1.42	0.23	HT:LP	1.24	0.31
			DT:LP	1.05(3)	0.17(3)

Table 60

Analysis of variance of weight of mesenteric fat (lb.)

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	5	0.740	0.247	1.93	ns
Plane of nutrition	1	0.225	0.225	1.77	ns
Treatment interaction	5	0.457	0.152	1.19	ns
Within subclass	32	4.107	0.128		
Total	39	5.529			

(B) SELECTED ORGAN WEIGHTS

(1) Thyroid gland

As the homogeneity of the variance between the group means was in doubt, Bartlett's test was applied. This test gave a χ^2 of 14.5185 for 9 d.f., $p>0.10$, indicating that the hypothesis of equality of the variances is acceptable. Therefore, an analysis of variance was carried out on thyroid gland weight, and the results of this analysis are presented in Table 62.

Table 61

Weight of thyroid glands(g.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	7.88	1.193			
C:NP	11.66	3.568	C:LP	8.00	1.131
LT:NP	7.80	2.562	LT:LP	7.18	1.009
MT:NP	9.30	2.345	MT:LP	7.30	2.498
HT:NP	7.78	2.445	HT:LP	9.72	3.167
			DT:LP	6.03(3)	0.515(3)

Table 62

Analysis of variance of weight of thyroid glands (g.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	28.57	9.52	1.54	ns
Plane of nutrition	1	11.77	11.77	1.91	ns
Treatment interaction	3	42.09	14.03	2.27	ns
Within subclass	32	197.30	6.17		
Total	39	279.73			

No treatment effects were detected on thyroid gland weight, although the mean value for the DT:LP group suggests that the combined treatments had reduced the weights of these glands. It was noted that all of the thyroid glands of the thyroxine treated ewes looked anaemic when compared to the thyroids of the control ewes.

(2) Liver

Both thyroxine treatment and a low plane of nutrition reduced liver weight.

Table 63

Liver weight (g.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	754	56.5			
C:NP	834	48.3	C:LP	635	47.8
LT:NP	722	64.8	LT:LP	627	45.3
MT:NP	648	13.3	MT:LP	539	40.2
HT:NP	737	99.2	HT:LP	586	24.3
			DT:LP	602(3)	35.0(3)

Table 64

Analysis of variance of liver weight (g.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	99668	33223	11.52	ss
Plane of nutrition	1	191961	191961	66.58	ss
Treatment interaction	3	16275	5424	1.88	ns
Within subclass	32	92270	2885		
Total	39	400172			

Standard error of the treatment means = 24.01g.
5% Fiducial limits = $\pm$ 49.05g.
1% Fiducial limits = $\pm$ 66.05g.

The mean liver weight of the CB group is lower than the C:NP group, probably as a result of the management this former group received immediately prior to slaughter. The low plane of nutrition has lowered the liver weight, of the C:LP ewes, and also at all levels of thyroxine treatment. Thyroxine has reduced the mean liver weight, with a greater reduction occuring on the normal plane of nutrition.

(3) Kidneys

Table 66 presents the statistical analysis for treatment effects upon the combined weight of both kidneys for each ewe.

Table 65

Kidneys weight (g.). (Two per ewe). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	141.2	9.07			
C:NP	159.4	6.73	C:LP	125.4	12.95
LT:NP	163.0	12.25	LT:LP	133.8	14.12
MT:NP	167.2	13.78	MT:LP	125.0	10.84
HT:NP	170.2	21.28	HT:LP	129.8	13.09
			DT:LP	125.3(3)	9.30(3)

Table 66

Analysis of variance of weight (g.) of two kidneys per ewe.

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	3	326	109	0.58	ns
Plane of nutrition	1	13286	13286	71.05	ss
Treatment interaction	3	268	89	0.48	ns
Within subclass	32	5984	187		
Total	39	19864			

Standard error of the treatment means = 6.1g.
5% Fiducial limits = $\pm$ 12.46g.
1% Fiducial limits = $\pm$ 16.78g.

The above tables show that the low plane of nutrition has reduced the combined kidney's weight for the controls and at all levels of thyroxine treatment. It may be noted that in all thyroxine implanted groups except MT:LP, the mean kidney is greater than for the corresponding control group. This agrees with the evidence on other

organs reviewed by Brody (1945, p.174). This difference did not reach significance.

(4) Spleen

The spleen weight showed no clearcut treatment effects and so no analysis of variance was carried out.

Table 67

Spleen weight (g.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	92.6	9.4			
C:NP	92.2	14.2	C:LP	105.6	7.4
LT:NP	108.6	25.5	LT:LP	92.4	13.7
MT:NP	100.8	11.1	MT:LP	99.4	15.6
HT:NP	110.4	11.6	HT:LP	112.8	10.1
			DT:LP	104.8(4)	12.6(4)

(5) Heart

Table 69 shows that plane of nutrition exerted a highly significant effect upon heart weight.

Table 68

Heart weight (g.). Group means and standard deviations.

Group	Mean	S.D.	Group	Mean	S.D.
CB.	260.2	28.1			
C:NP	270.4	18.0	C:LP	239.4	21.5
LT:NP	296.6	29.4	LT:LP	255.0	25.0
MT:NP	258.6	29.5	MT:LP	257.6	25.2
HT:NP	288.6	24.0	HT:LP	259.2	15.8
			DT:LP	262.8(4)	58.2(4)

Table 69

Analysis of variance of heart weight (g.).

Source	d.f.	S.S.	M.S.	F	
Thyroxine treatment	5	5459	1146	1.99	ns
Plane of nutrition	1	6631	6631	11.53	ss
Treatment interaction	5	2259	753	1.31	ns
Within subclass	52	18598	575		
Total	59	30727			

Standard error of the treatment means = 10.72g.
5% Fiducial limits = ± 21.9g.
1% Fiducial limits = ± 29.5g.

At all levels of thyroxine treatment except the medium level, the low plane of nutrition has reduced heart weight. Although the effects due to thyroxine treatment did not reach significance, it should be noted that in all cases except the MT:NP group, the mean weights of the thyroxine treated groups are greater than their respective controls. This is suggestive of hypertrophy of the heart, which has been observed by other workers to occur in thyroxine treated animals, (Brody, 1945, p.174).

DISCUSSION

No treatment effects could be demonstrated on the weights of omental or mesenteric fat, although the reduced weight of these depots in the DT:LP group, which was not included in the analyses of variance, were suggestive of treatment effects. These results agree with those of Robinson (1948), who was unable to demonstrate a loss of fat from the internal depots of ewes which had lost up to 53% of body weight.

The weights of the thyroid glands did not indicate any treatment effects, although all the glands from the thyroxine treated animals were anaemic as compared to those of the control animals. The only exception was the DT:LP group where the low mean weight and low variability suggest that the weights of the thyroids from these ewes had been reduced.

Both treatments have caused highly significant effects on liver weight. The reduction in liver weight attributable to a low plane of nutrition was in agreement with a large body of similar evidence in the literature. The weight loss of the C:LP livers was 24% when compared to the C:NP livers. It was to be expected that a low plane of nutrition would cause a loss of stored material from the liver.

Less expected was the highly significant reduction in liver weight caused by thyroxine treatment. For the MT:NP group this was a reduction of 22% when compared to the C:NP group. This disagrees with the evidence reviewed by Brody (1945, p.174), who suggested that thyroxine treatment caused hypertrophy of the liver. As the present results leave no room to doubt that thyroxine has caused a reduction of liver weight,

the most likely explanation for this apparent disagreement is the high levels of thyroxine treatment involved in this experiment and species differences are another possibility.

The reduction of kidney weight caused by a low plane of nutrition, and the suggestion of thyroxine induced hypertrophy, are in agreement with other workers' results.

The present data on spleen weight did not agree with the findings of Keys et al. (1950), that the spleen normally loses more weight than the body as a whole during starvation. However, Robinson's (1948) data on submaintenance ewes support the results of the present experiment. These differences may be a feature of the sheep as a species, or may be due to the less severe undernutrition in the sheep investigations.

A low plane of nutrition has reduced heart weight, and as for the kidneys, there appeared to be a tendency for thyroxine to increase heart weight.

Thus in general, a low plane of nutrition has caused a reduction in organ weight which was previously observed for the digestive tract. The only statistically significant result of thyroxine treatment on the organ weights available for analysis was a lowering of liver weight and as was noted earlier a lowering of gastric weight. Neither treatment was effective in lowering the weight of omental or mesenteric fat depots.

CHAPTER VIII

GENERAL DISCUSSION

At no stage, throughout the experimental data, could differences due to the three levels of thyroxine implantation be detected on liveweight and its components. Implantation effects, where present, were usually greater on the normal plane of nutrition than on the low plane. Treatment with 5mg. l-thyroxine injected per day on a low plane of nutrition (DT:LP) showed the severest effects in most cases. This result suggested that the rate of uptake of thyroxine from the implant tablets was less than 5mg. l-thyroxine per day. Confirmation of this came from the chemical analyses of a limited number of residual implants.

Thyroxine therapy and a low plane of nutrition, singly and in combination, caused highly significant losses of liveweight. As compared to the normal plane control ewes (C:NP), the normal plane implanted ewes and the low plane control ewes (C:LP) lost 13.8 lb. and 14.0 lb. respectively over the 28-day period. On the same comparative basis, the low plane implanted ewes lost 21.5 lb. liveweight and the low plane ewes given a daily injection of thyroxine (DT:LP -- 3 surviving for 28 days) lost 27.8 lb. liveweight. The remaining 2 ewes in the latter group, which did not survive the experimental period, lost about 30 lb. liveweight in 16 days. All of the above liveweight losses occurred over and above the mean loss for the total 50 experimental ewes of 14.5 lb. liveweight during the 35 day pre-experimental period. For the 28 days of the experiment, weight losses of up to 1 lb. per day were safe while losses of 2 lb. per day proved fatal.

Because of the treatment effects on liveweight, it was surprising to find that the group mean carcass weights showed no treatment effects. However, the treatments may have lowered carcass in the low plane;daily thyroxine injection group (DT:LP) which was not included in the statistical analysis, because only three carcasses were available.

No treatment effects could be demonstrated on weight of carcass fat, weight of fat from the carcass cuts, or on any internal fat depots measured. However, it appeared that the mean weights in the low plane:daily thyroxine injection group not included in the analysis of variance, may have been reduced in some cases. In view of the large body of evidence which shows that during bodyweight loss, fat is usually the first and most seriously affected tissue, this result was unexpected.

Despite the fact that some large liveweight losses were recorded over the period that liveweights were measured, the average carcass fat percentage was 40.4 for the 48 ewes which survived the experimental period. This indicated the difficulties to be faced in trying to remove fat from animals such as the overfat ewe.

Thyroxine treatment and a low plane of nutrition, singly and in combination, have lowered the weight of muscular tissue in the carcasses. This could also be looked at from the chemical point of view. Thyroxine caused dehydration of the fat free body, and analyses of muscular tissue which contributes largely to the weight of the fat free body, showed evidence of thyroxine induced dehydration. A low plane of nutrition caused loss of carcass protein. The combined weight of the bones from the leg joint indicated no treatment effects.

The data from the leg, loin and rib cuts showed regional carcass treatment differences, but the overall results are in general agreement with those for the carcass as a whole.

The above results indicate that it is unlikely that fat in the ewe can be reduced by either of the treatments imposed, at least in a limited period of 28 days, and without endangering the lives of the animals concerned. On the evidence available it would appear that the farmer must take a longer term view, and prevent his ewes from putting on the surplus fat by controlling their nutrition.

The evidence in the literature suggests that thyroxine will reduce body fat, but

apparently a period of time longer than 28 days, or a faster rate of uptake of thyroxine from the implants, is needed before thyroxine can significantly reduce fat weight. More information than is currently available, is needed on the rate of uptake of thyroxine from the implant tablets. As muscular tissue (and protein) were removed on a low plane of nutrition, it appears desirable that future experiments should be planned to further elucidate the manner in which ewes lose weight. Information is needed on the importance of these losses with particular reference to effects on fatty and muscular tissues.

This experiment makes clear the limitations of using liveweight as a criterion for experimental results. This is particularly important in meat studies, nutritional studies, and efficiency studies.

A further point which has been clearly demonstrated is the importance of the non-carcass liveweight loss. One of the ways by which thyroxine has reduced liveweight is by causing a loss in the weight of both the stomach and intestinal contents. Thyroxine therapy has also reduced gastric weight. Reduced weight of the gastrointestinal tract and contents together accounted for up to 6 lb. liveweight loss on the normal plane of nutrition. The low plane of nutrition caused surprisingly little reduction of gastrointestinal contents, but caused a highly significant reduction in the weight of the empty tract. The combined treatment effects on gastrointestinal tract (empty), and contents accounted for up to 8 lb. of the total liveweight loss. "Fill" alone accounted for 5 lb. of the 8 lb. loss of weight. This again re-emphasizes the dangers of taking liveweight as an indicator of treatment effects on ruminants.

A low plane of nutrition has caused a demonstrable reduction in the weight of all organs measured, except for the thyroid gland and the spleen. Thyroxine reduced gastric weight and liver weight, had no effect on intestinal weight, spleen weight or thyroid weight, and there were suggestions of thyroxine induced hypertrophy for heart and kidney weights. Thus in total the treatments appeared to have caused most weight

reductions in the offal fraction of the ewe body. The thyroxine induced dehydration of the fat free carcass suggests that the weight of blood in the body may also have been reduced.

Microanalyses of mince from the thyroxine implanted sheep suggest that this treatment leaves the carcass safe for human consumption, provided that the residual implants are totally removed at slaughter. It was noted that all implanted sheep showed wool break at skin level as compared to the controls. This however does not matter in animals which are soon to be slaughtered.

The bandsaw technique has for the first time made possible the chemical analyses of complete large animal carcasses. The accuracy of sampling achieved by the use of large quantities of mince produced results which agree well with other similar chemical work. The results using these methods are obtained far more quickly than by the use of complete dissection methods, and give much more information than the "percentage cuts" approach of American workers. However, dissection work can be carried out in conjunction with the bandsaw technique as was done in this experiment. It should be noted that similar results were obtained no matter whether the bandsaw or dissection methods were employed.

CHAPTER IX

SUMMARY AND CONCLUSIONS

(1) An experiment is described involving 50 Romney crossbred ewes of known history. These ewes were randomised to 10 treatment groups of approximately equal mean liveweight. Each group consisted of five ewes. Three levels of l-thyroxine implantation were used on groups of ewes on both a normal and a low plane of nutrition, and a daily thyroxine injection group was included on the low plane of nutrition. The average liveweight of the ewes was 147 lb. at selection and 135.5 lb. at the beginning of the 28-day experimental period.

(2) Liveweight losses of up to 24.4 lb. for the low plane:low thyroxine group (LT:LP) and 30.0 lb. for the three surviving ewes of the low plane:daily thyroxine group (DT:LP) were recorded during the experimental period. In the latter group, the daily injection of 5mg. l-thyroxine resulted in two deaths before the completion of the experimental period and this treatment had to be curtailed.

(3) Metabolic studies on a further ewe injected daily for 5 days with 5mg. l-thyroxine on an *ad libitum* diet, at the completion of the main experiment, indicated that the oxygen consumption was increased by at least 50% and the respiration rate was at least doubled by this treatment.

(4) No treatment effects were demonstrated on carcass weight. The mean hot carcass weight was 61.8 lb. (range 43.1 lb. - 78.8 lb.).

(5) There were no demonstrable treatment effects on the weight of carcass fat or on weight of the internal fat depots. The carcasses averaged 40.4% chemical fat, (range 24.9% - 54.5%).

(6) Both thyroxine treatment and a low plane of nutrition and the combination of the two treatments reduced the weight of the chemical fat free carcass. Thyroxine lowered the percentage carcass water on a chemical fat free basis which was indicative of tissue dehydration. A low plane of nutrition lowered the weights of both protein and

water in the carcass, which suggested the loss of muscular tissue. This loss of muscular tissue was confirmed from the dissection results.

(7) No treatment effects could be shown on the weight of bone from the leg joint.

(8) Dissection results from the leg, loin and rib cuts, and chemical work on the rib cut showed some regional treatment differences, but, in general, the results confirmed those on the carcass as a whole.

(9) Thyroxine therapy caused a lowered weight of gastrointestinal contents and this was attributed to an increased rate of passage of food through the tract. A low plane of nutrition and a longer starvation period prior to slaughter had surprisingly little effect on the weight of gastrointestinal contents. Alimentary "fill" accounted for a group mean loss of liveweight of up to 5 lb.

(10) Thyroxine reduced gastric weight, while a low plane of nutrition reduced both gastric and intestinal weight. The combined treatment effects accounted for a loss of up to 3 lb. in the weight of the empty gastrointestinal tract.

(11) A low plane of nutrition reduced the weight of the liver, kidney and heart and produced no effects on spleen weight and thyroid weight. Thyroxine treatment reduced liver weight.

(12) In no case could consistent differences be demonstrated between the three levels of thyroxine implantation, namely 150mg., 210mg. and 270mg. l-thyroxine. The daily thyroxine injection treatment proved more severe than implantation.

(13) Thyroxine implantation at the above levels caused a wool break at the skin surface in all treated ewes.

(14) Microchemical iodine analyses of minced carcass samples suggested that there is unlikely to be sufficient thyroxine in the meat to make it unsafe for human consumption, provided that care is taken to remove any residual implants.

(15) The proportion of water in the fat free carcass of the control ewes was 71.9%. This agrees well with the figure of 72 - 73% water which has been calculated as a

"biological constant" in other species. This water percentage was reduced by thyroxine treatment, and was found to be uncorrelated with the weight of carcass fat.

(16) Preliminary analyses revealed that the proportion of water in the fat free rib muscle of the control ewes was 77% which agrees with the figure proposed by Callow (1947) for the fat free boneless meat from frozen stored carcasses. This proportion was reduced by thyroxine treatment thus indicating dehydration.

(17) The bandsaw technique used has made possible the chemical analyses of whole carcasses from large animals. The macrochemical technique adopted, permitted the analysis of six 50g. samples per half carcass. The low standard errors of the means and coefficients of variation suggest that this method was successful. The use of the above methods made the analyses of the 48 half-carcasses studied in this experiment a practical possibility.

PART II

INDICES OF CARCASS COMPOSITION

CHAPTER I

INTRODUCTION

Studies on the development of meat animals and the efficiency of meat production, as affected by breeding and feeding, are primarily concerned with changes in the fatty, muscular and bony tissues. The proportions of these tissues at any given stage of development are of interest to the producer, meat grader, butcher and especially to the consumer. Fatness greatly affects the acceptability of meat to the consumer, and it is well known that the fattening period is the most costly phase of animal feeding.

In the majority of animal production experiments, liveweight, and in some cases carcass weight, are used as the only criteria for the effectiveness of the treatments and of the nutritional status of the animals. Rarely is the body and/or the carcass composition determined. It is known that bodyweight, even when evaluated with reference to size of skeleton, is a poor measure of fatness (Keys and Brožek, 1953). No research worker has yet clearly specified the relationship between carcass weight and composition, although there is evidence to suggest that such a relationship exists. It is probable that the cost of chemical or dissection analyses, in terms time and labour, meat destroyed and the value of chemicals and equipment, is the reason for the lack of information on the end product in many animal husbandry experiments.

As chemical and dissection methods were used to test the experimental treatments used on the ewes in PART I, the data on the carcasses from these ewes were also suitable for a study on indices of carcass composition, and little additional work was necessary to obtain the extra information. Some data from earlier dissection work carried out in the Sheep Husbandry Department were also available for study.

Better information than is at present commonly collected, can be obtained without much extra cost, by the use of indices of carcass composition. These indices include information available on the entire carcass, information on part of the carcass (e.g. sample joints), and information from the offal or non-carcass portion of the body.

For example, many workers have recently suggested that carcass specific gravity is a good index of the proportion of fat in the carcass. When the relationship between carcass specific gravity and carcass fat percentage has been elucidated for a given breed or species, then the composition of similar carcasses may be estimated from their specific gravity and the carcasses may still be saleable at the completion of the experiment. By using indices of carcass composition, the accuracy of evaluation of experimental treatments may be increased at small extra cost.

CHAPTER II

REVIEW OF LITERATURE

(A) INFORMATION ON THE ENTIRE CARCASS AND ENTIRE JOINTS (WITH PARTICULAR REFERENCE TO INDICES OF FATNESS)

(1) Carcass weight

Carcass weight is an item of information which is usually collected at slaughter in most animal research institutions. Smith-Pilling and Barton (1954) present evidence which suggests that fat is the major factor affecting carcass weight. Clarke and McMeekan (1952), reporting on lamb and mutton carcasses, show that within quality grades there is a decrease in the proportion of bone and muscle and an increase in the proportion of fat with increasing carcass weight. This is also suggested by the work of McMeekan (1940, 1941) on the growth of the pig. The relationships between carcass weight and carcass components, particularly for carcass fat, have not yet been calculated.

(2) Carcass measurements

Many workers have calculated relationships between linear measurements on the carcass and on its cut surfaces, and the composition of the carcass.

(3) Carcass specific gravity

The density of body fat is considerably less than that of the other body and carcass components, and hence the larger the proportion of fat, the lower will be the density of the whole body or of the carcass. Morales *et al.* (1945) show that for theoretical reasons "the plot of percentage body fat versus body specific gravity should be a rectangular hyperbola displaced from its principal x axis." They also deduce from purely dimensional considerations that the nature of the relationship between the mass of any body component and the average body density is not linear but hyperbolic.

The specific gravity technique was first successfully used to determine the proportion of fat in the human body by Behnke *et al.* (1942). Behnke (1945) suggested a value of 1.10 for the specific gravity of the fat free body mass.

A direct validation of the use of specific gravity for determining body fat was obtained by Rathbun and Pace (1945) when they analysed the whole body for fat, in a series of 50 eviscerated guinea pigs of which the specific gravities of the carcasses and of the viscera of 21 animals had been previously determined. The relationship between body fat and specific gravity has since been reported on for cattle (Kraybill et al., 1952) and for pigs (Kraybill et al., 1953).

Validation of the specific gravity method in carcass studies has been demonstrated for the albino rat (Da Costa and Clayton, 1950), the pig (Brown et al., 1951), cattle (Kraybill et al., 1952) and for the ewe (Barton and Kirton, 1956). Correlation coefficients between carcass specific gravity and carcass fat (ether-extract in some cases and separable fat in others) of up to 0.79 for the albino rat, 0.75 for the pig, 0.956 for cattle and 0.877 for the ewe were reported by the above workers. Some preliminary results from the use of specific gravity on lamb carcasses were given by Stouffer (1955), who found a correlation of ~~0.662~~ 0.62 between carcass specific gravity and ether-extract.

It may be noted that the relationships between specific gravity and fat found for cattle and for guinea pigs ($r = 0.972$) were higher than those obtained in the rat and pig experiments. This may be due to the smaller number of animals involved in the former experiments, which may have allowed more careful determination of the specific gravity. Also, the fact that the cattle carcasses were quartered would lower the chance of air being trapped in the carcasses and so reducing the accuracy of the specific gravity determinations. As a hyperbola was fitted to the cattle and guinea pig data and a straight line was fitted to the pig and albino rat data, this may help to explain the higher correlations in the former cases.

Of special interest are the results of Rathbun and Pace (1945) which showed that the fat content of the whole animal (guinea pig) is equivalent to that of the eviscerated carcass over the entire range that they studied. Because of this, the correlation between whole animal specific gravity and carcass specific gravity of 0.962 was to be

expected.

The specific gravities of various carcass cuts have also been used for predicting their composition for both cattle and pigs, (Brown et al., 1951; Kraybill et al., 1952; Whiteman et al., 1953; Lofgreen et al., 1954; Pearson et al., 1956). The specific gravities of cuts have been used for predicting carcass fat as estimated from the three rib cut by Kraybill et al. (1952) in cattle. Carcass specific gravity has been used to estimate the percentage fat in various cuts from the ewe by Barton and Kirton (1956). The specific gravity of a cut has also been correlated with other carcass items such as areas of components of the ham and various carcass measurements in the pig by Fredeen et al. (1955a, 1955b).

Various workers have specified the following factors which must be taken into account in the determination of specific gravity:-

(a) Water temperature

As the specific gravity is the ratio of the density of the body or the carcass to the density of water, it is an abstract number independent of the units of measurement. However, both the temperature of the body or carcass being measured and of the water must be specified. The importance of water temperature as a factor in specific gravity work was discussed by Keys and Brožek (1953). Whiteman et al. (1953) considered that water temperature changes of within 20°F. are of no practical importance.

(b) Repeatability of specific gravity

Whiteman et al. (1953) noted that freshly dressed pig carcasses float and so specific gravity measurements should be made on chilled carcasses which sink. It was noted by Kline et al. (1955) that the specific gravity readings for 0, 24, 48 and 72 hours of chilling were 0.9965, 1.0214, 1.0249 and 1.0276 respectively on pig carcasses. It is probable that the temperature of the carcass is a major factor contributing to these differences. Kline et al. also report that the correlations between specific gravity and various fat measurements were maximal at 24 hours, and then decreased after 72

hours to values approximating those at zero hours. They suggest that these changes in specific gravity point to the necessity of making determinations at a uniform chilling time.

For a period of up to three hours, the longer a carcass is left in water the less is its specific gravity. Because of this, a second reading taken a few minutes after the first will be less than the first, (Whiteman et al., 1953). Uptake of water by the carcass as well as carcass temperature changes could be factors leading to these results.

(c) Trapped air

For obvious reasons, great care must be taken to avoid trapped air in the carcasses.

(d) Carcass components other than fat

Carcass components, apart from fat, are likely to effect carcass specific gravity. As Keys and Brožek (1953) pointed out, there will be some variations due to different amounts of bone present. This factor was, however, small as the standard deviation of bone as a percentage of the fat free body was found to be approximately equal to 0.5% for the rat, rabbit, guinea pig and cat. The state of hydration or dehydration of the animal's body is also important.

(4) Dressing percentage (carcass weight as a percentage of liveweight)

The first attempt to relate fatness of beef animals to dressing percentage was made by Lawes and Gilbert (1859). Lush (1926), on the basis of 50 steers, found a correlation of 0.84 ± 0.036 between dressing percentage and percentage of fat in the entire live animal. On a greater number of animals, where there were differences due to breed and in slaughter techniques, this correlation was lower. This lower correlation could also be influenced by the basis of calculating the dressing percentage (hot or cold carcass weight), and the treatment of the animal prior to slaughter, which could influence "fill" and certain organ weights. Lush concluded that while dressing percentage is a good general indicator of fatness, it is affected by too many other

things to be very trustworthy, particularly if the animals studied have a small range of fatness.

Hankins and Titus (1939) suggested that one of the most obvious and best known changes that accompany growth and fattening is the increase in dressing percentage. They quote from data on 5000 normally fed hogs that varied from 60 - 380 lb. in final feed-lot weight. Increase in weight was accompanied by an increase in dressing percentage from 67 to 80. Similar figures are quoted for cattle and lambs. As fat is the last major tissue laid down in the carcass, and thus will constitute a greater portion of each extra increment of carcass weight, one would espect a correlation between percentage fat in the carcass and dressing percentage. Callow (1944) also related state of fatness to dressing percentage in beef cattle. Thus dressing percentage was correlated 0.93 with fatness as expressed by the ratio of fatty tissue in the carcass as a percentage of liveweight.

Annan and Winters (1949) found a correlation of 0.659 between dressing percentage and backfat thickness in the pig. The yield of the carcass in terms of the five primal cuts (ham, picnic, loin, belly and Boston Butt) was not associated with dressing percentage.

(B) INFORMATION ON A PART OF THE CARCASS (e.g. SAMPLE JOINTS)

Two main regions of the carcass have been used as sample joints. The three rib cut (9-10-11 ribs) has been the sample joint favoured by American workers, probably because much of their meat work concerns cattle, for which the other sample joints used may prove too bulky for large scale experiments. Other workers have followed the methods developed by Hammond (1932) of the Cambridge school and have shown preference for the leg plus loin. They were chosen because they include an early and a late developing joint, they are accurate indices of carcass composition and they are relatively easy to dissect. This approach, thus far, has been followed on sheep and pigs.

(1) The rib cut

On the available information, Lush (1926) concluded that the portion of the beef animal most frequently analysed to determine level of fatness was the wholesale rib cut. A linear correlation of +0.987 $\pm$ 0.003 was obtained between percentage fat in the entire live animal and percentage fat in the rib cut. This index of body fatness was more reliable than any other indicator looked at. The correlation between fat in the entire live animal and fat in the edible meat of the carcass was almost unity suggesting that the wholesale rib cut is an equally good indicator of carcass fat.

Hankins et al. (1945) found the correlation coefficients between the 9-10-11 rib cut and the dressed carcasses of cattle to be for the following separable components; fat 0.93, lean 0.90 and bone 0.80. The appropriate regression equations were given.

Hopper (1944) made use of the published cattle data from Missouri and North Dakota. He looked at relationships between the components of the wholesale rib cut, the 9-10-11 rib cut and the edible portions of these cuts as compared to these same components in the edible and non-edible carcass. The constituents studied included separable fat, lean and bone; and the chemical ether-extract, protein, water and ash. A large number of correlations and regression equations was presented for these data. Most correlations and particularly those for measures of fatness were well over 0.9.

Hankins and Howe (1946) also have data on the physical and chemical constituents of the 9-10-11 rib cut and the whole carcasses for 120 cattle. They calculated lower correlations than Hopper; those for separable fat and ether-extract were the highest (r = 0.93). The equations of Hopper and those of Hankins and Howe seem to be the standard ones used for estimating purposes in U.S.A., using mainly the relationship between the carcass and the 9-10-11 rib cut.

The wholesale rib cut (9 ribs) has been used as an index of the composition of lamb carcasses, (Hankins, 1947). A correlation between the separable fat of this cut and the carcass as a whole of 0.98 was shown. A similar high correlation was found for ether-extract. In New Zealand lamb and mutton carcasses, Shorland et al. (1947)

found a correlation of 0.99, between percentage ether-extract in the edible meat of the thorax and that of the rest of the carcass. The thorax in this case would include the 9-rib cut of Hankins' lamb data.

The above work suggests that the wholesale rib cut or a 9-10-11 rib cut can be a good sample joint for predicting the composition of the carcass as a whole and in particular for predicting its fat content.

(2) Leg and the loin

The use of these joints in combination, as indices of carcass composition of the sheep, was suggested by Pálsson (1939). He considered them suitable because they can be cut with precision, give information on a valuable portion of the carcass, are easy to dissect and include an early and a late developing region of the carcass. Correlations between the fat, muscle and bone in the sample joints and the same constituents in the whole carcass approached unity for eleven lambs and five hoggets. It was always found that the correlation for the joint component as compared with the same component of the total carcass was slightly less than for the combination of both joints.

For the ether-extract of edible portion of the leg and loin, Shorland et al. (1947) found in New Zealand lamb and mutton, correlations with the same fraction of the total carcass of 0.86 and 0.97 for these two joints respectively. Unfortunately the combination of leg plus loin was not tested. Pálsson and Vergés (1952) also describe the use of sample joints on the sheep.

McMeekan (1941) found the combination of leg plus loin was of higher predictive value than either leg or loin alone, for the dissectible constituents of the pig.

(3) Carcass chemical components as indices of carcass composition

Callow (1942) and Shorland et al. (1947) have shown that the chemical components of water, protein and fat in the edible carcass are closely interrelated.

(4) Coring device

The use of a coring device to obtain a carcass sample was suggested by Aunan and Winters (1952). The results, as expected, were not as accurate as those obtained from the use of sample joints.

(C) INFORMATION FROM THE OFFAL PORTION OF THE ANIMAL

The offal portion of the body may provide information on the carcass and so prevent the destruction of saleable meat, as occurs when sample joints are used. Cannon bones have the added advantage that they can be stored for future reference.

(1) Internal fat depots

Lush (1926) suggested that the percentage of offal fat to liveweight may be used as a measure of fatness for cattle. The offal fat consisted of caul fat, ruffle fat (from mesentry) and gut fat. The correlation between the percentage of fat in the entire live animal and percentage of offal fat to liveweight, over a very diverse group of cattle was 0.838 ± 0.031. For a uniform group of cattle this correlation was 0.938 ± 0.015. Lush suggested that the results must be viewed with caution as there may be sex differences which could not be estimated in his data, and there was some slight evidence for breed differences.

Lush also used the ratio of percentage caul fat to liveweight as an indicator of fatness, and this was a fairly easy measurement to obtain. It was not however as good an indicator of fatness as total offal fat. Using a combination of dressing percentage and percentage offal fat as an indicator of fatness, Lush found a correlation of 0.966 between this combination and fat in the entire live animal. With a combination of dressing percentage and percentage caul fat he calculated correlations between this combination and the fat in the entire live animal of 0.917 over the total data and 0.941 for a uniform group of steers.

(2) Internal organs

In an interesting study on stored data from many sources, on 165 cattle, Kraybill

et al. (1954) studied the degree of association between the weight of the visceral organs (spleen, liver, heart, kidney and pancreas) and the weight of the lean body mass and empty body weight. There was a very high positive correlation between the organ weights and both weight of empty body and lean body mass (up to 0.98 between lean body mass and liver weight for one group of cattle studied). All of the visceral organs used were about equally reliable in their predictive values. For a population of cattle limited in age and weight, the liver appeared to be a better indicator than the other organs. However, for cattle varying more widely in age, weight and degree of fatness, all organs are good indicators.

(3) Cannon bones

It has been found for lambs and hoggets (Pálsson, 1939) and for pigs (McMeekan, 1941) that the weight of the cannon bones gave an excellent indication of the weight of bone in the carcasses.

CHAPTER III

MATERIALS AND METHODS

The 48 carcasses which were analysed as described in PART I of this project were considered suitable for a study on indices of carcass composition. It has been shown that no treatment effects were demonstrated on carcass weight or on any measure of fat taken. It should be recalled, however, that treatment effects were observed on carcass protein and water and also on dissectible muscular tissue. The question arises as to whether the regression equations calculated for these latter constituents will give valid predictions for the general population, assuming that these data were originally a representative sample. There is not sufficient evidence available in the literature from which to decide whether the treatment induced changes are similar to those found under "normal" conditions or not. As most of the observed treatment effects, although significant, were not of very great magnitude, it is considered that the use of the present data should not lead to very large predictive errors.

Some data from earlier dissection work carried out in the Sheep Husbandry Dept. were also available for study. Twenty five ewe carcasses had been selected for this work from the freezing chamber of a meat works, to cover the normal range of carcass weight. These are likely to be Romney-crossbred carcasses.

CHAPTER IV

RESULTS

(A) INFORMATION ON THE ENTIRE CARCASS AND ENTIRE JOINTS (WITH PARTICULAR REFERENCE TO INDICES OF FATNESS)

(1) Carcass weight

Carcass weight has been correlated with both chemical and dissectible carcass fat. The 48 carcasses had a mean weight (cold) of 60.4 lb., (range 41.5 - 77.4 lb.) The mean weight of chemical fat was 24.7 lb. (range 10.5 - 37.0 lb.) Also included here are three correlations between body weight at the beginning of the experimental period and estimates of carcass fatness. The correlations were included to test the assumptions made in planning this experiment; that ewes of equal body weight should have carcasses of approximately equal fatness.

Table 70

Correlation coefficients between cold carcass weight (lb.) and between body weight (lb.) at the beginning of the experimental period, and components of carcass weight.

Carcass component	Carcass weight (48 ewes)		Body weight 45+ ewes	
Carcass chemical fat (lb.)	0.9134	ss	0.7088	ss
Carcass chemical fat (%)	0.7010	ss	0.4375	ss
Leg + loin dissected fat (g.)	0.8538	ss	0.5481	ss
Rib cut chemical fat (g.)	0.8371	ss	-	
Carcass water (lb.)	0.6730	ss	-	

+The three daily thyroxine treated ewes were excluded because there appeared to be treatment effects on carcass fat in this group. These ewes were, however, suitable for the carcass weight correlations because this had also been reduced in the DT:LP group.

The mean weight of the 25 dissected carcasses was 60.6 lb., (range 37.9 - 80.8 lb.) The mean weight of dissected fatty tissue from these carcasses was 21.5 lb., (range 10.2 - 40.9 lb.) The correlation coefficient between carcass weight (lb.) and weight of dissectible fat was 0.9391 ss .

Regression equations were calculated between carcass weight and weight of carcass fat.

Table 71

Regression equations for estimating weight of carcass fat from carcass weight (lb.) Dependent variate (weight of fat in the carcass, lb.) = Y

	Independent variate = X	Regression Equation	$S_{y.x}$
48 carcasses (chemical data)	Carcass weight (lb.)	Y = 0.7202X - 18.80	2.54 lb.
25 carcasses (dissection data)	Carcass weight (lb.)	Y = 0.6077X - 15.39	2.72 lb.

(2) Specific gravity of the carcass and of the joints

The specific gravities of the carcasses were determined at a water temperature of 17 - 20°C. The surface temperature of the chilled carcasses was 11 - 12°C. Table 72 presents the means and ranges for specific gravities and fat and water percentages.

Table 72

Specific gravities, fat and water percentages. Means and ranges.

Item	Number	Mean	Range
Carcass specific gravity	48	1.029	(1.009 - 1.054)
Rib cut specific gravity	45+	1.013	(0.991 - 1.039)
Leg specific gravity	48	1.049	(1.030 - 1.076)
Loin specific gravity	45+	1.007	(0.984 - 1.035)
Half carcass chemical fat %	48	40.4	(24.9 - 54.3)
Rib cut chemical fat %	48	50.9	(33.4 - 68.3)
Rib cut dissected fat %	48	51.0	(31.4 - 69.5)
Leg dissected fat %	48	25.4	(16.2 - 34.7)
Loin dissected fat %	48	43.7	(25.3 - 62.2)
Half carcass water %	48	42.2	(31.8 - 52.7)
Rib cut water %	48	34.7	(22.4 - 48.8)

+The method used to determine the specific gravities of the joints proved unsatisfactory in the early stages due to technical difficulties and some of these data had to be discarded.

Table 73 presents the correlations between the specific gravities of the carcasses and other variables.

Table 73

Correlation coefficients between specific gravities (S.G.) of the carcasses and other variates, (chemical data unless otherwise stated.)

Other variate	No. of pairs	Carcass S.G.		$\frac{1}{\text{Carcass S.G.}}$	
Carcass side % fat	48	-0.8417	ss	0.8405	ss
Carcass side % fat (NP. thyroxine treated)	15	-0.8255	ss	0.8211	ss
Carcass side % fat (LP. thyroxine treated)	15	-0.9060	ss	0.9058	ss
Carcass side % fat (Control ewes)	15	-0.8769	ss	0.8724	ss
Carcass side % water	48	0.7873	ss	-0.7849	ss
Rib cut % fat	48	-		0.8589	ss
Rib cut % fat (dissected)	48	-0.7841	ss	0.7809	ss
Rib cut % water	48	0.7928	ss	-	
Rib cut specific gravity	43	0.6224	ss	-	
Leg fat % (dissected)	47	-0.5860	ss	-	
Leg specific gravity	47	0.5947	ss	-	
Loin fat % (dissected)	48	-0.7311	ss	-	
Loin specific gravity	44	0.6648	ss	-	

Table 74

Correlations between joint specific gravities and state of fatness of the joints.

Variates	No. of pairs	Correlation coeff.	
Rib % chemical fat and rib specific gravity	43	-0.7870	ss
Rib % dissected fat and rib specific gravity	43	-0.8938	ss
Leg % dissected fat and leg specific gravity	48	-0.8161	ss
Leg % dissected fat and $\frac{1}{\text{leg specific gravity}}$	48	0.8161	ss
Loin % dissected fat and loin specific gravity	45	-0.7950	ss

The above figures show that in nearly all cases, specific gravity is a good indicator of state of fatness. By using the relationships in Table 73 it was possible to predict the fat and water percentages of the ewe carcasses within the ranges presented in Table 72. The appropriate regression equations are presented in Table 75.

Table 75

Regression equations for predicting carcass composition from carcass specific gravity (S.G.)

Dependent variate (% chemical fat in the carcass) = Y
Dependent variate (% water in the carcass) = Z

Population	No. of pairs	Independent variate = X	Regression equation	$S_{y.x}$
Control ewes	15	Carcass S.G.	$Y = 578.6 - 525.8X$	3.12%
Control ewes	15	Carcass $\frac{1}{S.G.}$	$Y = \frac{544.1}{X} - 489.3$	3.17%
NP:Implanted ewes	15	Carcass S.G.	$Y = 438.9 - 386.5X$	2.88%
NP:Implanted ewes	15	Carcass $\frac{1}{S.G.}$	$Y = \frac{408.3}{X} - 355.7$	2.91%
LP:Implanted ewes	15	Carcass S.G.	$Y = 534.0 - 479.2X$	2.55%
LP:Implanted ewes	15	Carcass $\frac{1}{S.G.}$	$Y = \frac{496.1}{X} - 441.3$	2.55%
Within above subclasses +	45	Carcass S.G.	$Y = 517.7 - 465.5X$	2.85%
Within above subclasses +	45	Carcass $\frac{1}{S.G.}$	$Y = \frac{484.0}{X} - 429.8$	2.87%
Total 48 ewes	48	Carcass S.G.	$Y = 537.8 - 8.483X$	3.24%
Total 48 ewes	48	Carcass $\frac{1}{S.G.}$	$Y = \frac{504.7}{X} - 450.3$	3.25%
Total 48 ewes	48	Carcass S.G.	$Z = 315.9X - 282.9$	2.59%

+That is within the control ewes plus within the NP:Implanted ewes plus within the LP:Implanted ewes.

It may be noted that the theoretically based curvilinear regression line gave results that were no more accurate than a straight regression line for predictive purposes.

A least squares method which has been used by Beltsville workers (Hiner, 1957. Personal communication), was used to estimate the specific gravity of the fat and the specific gravity of the fat free carcass, from those above equations which are based on the reciprocal of carcass specific gravity. The method used is specified in the appendix. The method used gave the results presented in Table 76.

Table 76

Estimated values for specific gravity of fat and specific gravity of fat free carcass.

Population	No. of pairs	Fat S.G.	Fat free carcass S.G.
Control ewes	15	0.9233	1.112
NP:Implanted ewes	15	0.8960	1.148
LP:Implanted ewes	15	0.9165	1.124
Within above subclasses	45	0.9136	1.126
Total ewes	48	0.9171	1.121

The above values for specific gravity of fat may be compared to a value of 0.8999 $\frac{25^{\circ}C}{25^{\circ}C}$ which was determined on the perinephric fat of five ewes from this experiment (Shorland, 1957. Personal communication). The values for the specific gravity of the fat free carcass are in relatively close agreement with the values of 1.098 and 1.094 (Keys and Brozek, 1953) as the specific gravities of the fat free body mass of man and guinea pigs respectively. The higher specific gravity values for the fat free carcasses of the implanted ewes as compared to the controls was to be expected, as it was shown in Tables 15 and 16 (PART I) that the fat free carcasses of the implanted groups were dehydrated.

(3) Dressing percentage

Table 77 presents the results of the correlations between dressing percentage (hot carcass weight/liveweight at slaughter) and percentage chemical fat in the carcasses of the experimental ewes. The mean dressing percentage was 53.4 (range 48.4 - 59.7).

Table 77

Correlations between carcass chemical fat and dressing percentage.

Population	No. of pairs	Correlation coeff.	
Control ewes	15	0.8694	ss
NP:Implanted ewes	15	0.7682	ss
LP:Implanted ewes	15	0.8218	ss
All ewes	45	0.8217	ss

The following regression equations were calculated for these data.

Table 78

Regression equations for predicting carcass chemical fat percentage from dressing percentage.
Dependent variate (% chemical fat in the carcass) = Y

Population	No. of pairs	Independent variate = X	Regression equation	$S_{y.x}$
Control ewes	15	Dressing %	Y = 1.794X - 55.5	3.2%
All ewes	45	Dressing %	Y = 1.593X - 44.4	3.2%

It is of interest to note that the carcass chemical fat percentage could be predicted as accurately from all ewes as it could be from the control sheep. This is in spite of the fact that thyroxine treatment lowered the weight of the gastrointestinal contents, one of the components of body weight.

(B) INFORMATION ON PART OF THE CARCASS

(1) The 9-10-11 rib cut

This is the rib cut referred to throughout the results sections of this experiment. The mean percentage protein of the rib cut was 10.93 (range 7.1 - 15.7%) and the mean carcass protein percentage was 12.52 (range 10.1 - 16.4%). The means and ranges for chemical and dissected fat and for water were presented in Table 72.

Table 79

Correlations between components of the rib cut and other rib and carcass components.

Variates	No. of pairs	Correlation coeff.	
Rib % chemical fat and side % chemical fat	48	0.9580	ss
Rib % dissected fat and side % chemical fat	48	0.9056	ss
Rib % chemical fat and rib % dissected fat	48	0.9162	ss
Rib % water and side % water	48	0.9548	ss
Rib % water and side % chemical fat	48	-0.9509	ss
Rib % water and rib % chemical fat	48	-0.9794	ss
Rib % protein and side % protein	48	0.8858	ss
Rib dissected muscle wt. (g.) and leg + loin muscle wt. (g.)	48	0.8009	ss
Rib protein wt. (g.) and rib muscle wt. (g.)	48	0.5865	ss

Table 79 suggests that the 3-rib cut is a suitable index of carcass composition in the ewe and so regression equations were calculated for this cut.

Table 80

Regression equations for estimating rib and carcass components of the ewe from components of the rib cut. (based on 48 pairs of observations).

Independent variate = X	Dependent variate = Y	Regression equation	$S_{y.x}$
Wt. rib chemical fat (g.)	Wt. carcass chemical fat (g.)	Y = 14.81X + 3499	877g.
% rib chemical fat	% carcass chemical fat	Y = 0.747X + 2.32	1.72%
Rib water %	Carcass water %	Y = 0.726X + 16.99	1.25%
Rib water %	Carcass fat %	Y = 75.58 - 1.014X	2.19%
Rib protein %	Carcass protein %	Y = 0.6798X + 5.09	0.70%

The low standard errors of estimate of these regression equations suggest that the three rib cut gives an accurate estimate of carcass composition. The use of rib protein % to predict that of the carcass has resulted in a low standard error of the regression equation but in this case the error is high proportionally because of the low range of protein percentages in the carcass.

(2) Leg and loin

The literature has shown that the dissectible components of the leg plus loin and of these joints individually are good indices of the dissectible components of the carcass as a whole. Dissection data were available for study from 25 ewe carcasses. These carcasses had a mean weight of 60.6 lb. (range 37.9 - 80.8 lb.) The mean weight of dissected fatty tissue was 21.5 lb. (range 10.2 - 40.9 lb.), of dissected muscular tissue was 29.6 lb. (range 20.1 - 37.7 lb.) and of bone was 6.2 lb. (range 4.6 - 7.8 lb.) Table 81 presents the relationships between the components of these joints and those of the carcass as a whole.

Table 81

Correlations between the dissectible components of the carcass and the same components of the leg and loin (stored data).

Variates	No. of pairs	Correlation coeff.	
Carcass fat (g.) and fat of leg + loin (g.)	25	0.9839	ss
Carcass fat (g.) and fat of loin (g.)	25	0.9743	ss
Carcass fat (g.) and fat of leg (g.)	25	0.9452	ss
Carcass muscle (g.) and leg + loin muscle (g.)	25	0.9725	ss
Carcass muscle (g.) and loin muscle (g.)	25	0.9265	ss
Carcass muscle (g.) and leg muscle (g.)	25	0.9540	ss
Carcass bone (g.) and leg bone (g.)	25	0.7096	ss

The relationship between a component of a sample joint and the same carcass component was closer for the combination of the leg plus loin than for the individual joints. The reason for the comparatively low correlation between leg bone weight and carcass bone weight as compared to higher values reported by other workers is not apparent. A possible explanation may be that other workers have studied a growth series, as opposed to the present experiment where mature animals have been used. Such a group of mature animals is likely to provide a more severe test of any relationship between two variables uncomplicated by growth. Regression equations were calculated for the above data.

Table 82

Regression equations for estimating dissected carcass components from dissected components of the leg and loin of 25 ewes.
Dependent variate (carcass fatty tissue.g.) = Y
Dependent variate (carcass muscular tissue.g.) = Z

Independent variate = X	Regression equation	$S_{y.x}$
Fatty tissue of leg + loin (g.)	Y = 955.2 + 4.178X	655.7g.
Fatty tissue of loin (g.)	Y = 1740.2 + 5.099X	807.2g.
Fatty tissue of leg (g.)	Y = 19.584X - 711.6	1176g.
Muscular tissue of leg + loin (g.)	Z = 1152 + 3.695X	462.6g.
Muscular tissue of loin (g.)	Z = 5280 + 6.052X	747.0g.
Muscular tissue of leg (g.)	Z = 287 + 8.015X	597.7g.

(5) Carcass chemical components

The literature indicates that the relationship between the chemical components of the edible meat in the carcass (fat, protein and water) are high and so it was

not surprising that this also applied to the chemically analysed whole carcass. The correlation coefficient between the % water in the half carcass and the % chemical fat in the half carcass was -0.9794 ss. The regression equation for predicting side % fat from % water was:-

% chemical fat = 99.51 - 1.401X where X = % carcass water. $S_{y.x}$ = 1.20%

A correlation was calculated between side % water and side % protein. This correlation was also caloulated within the control sheep and within the thyroxine treated ewes.

Population	Correlation coeff.
Total 48 ewes	0.8055 ss
15 control ewes	0.8725 ss
33 thyroxine treated ewes	0.8414 ss

(C) INFORMATION FROM THE OFFAL PORTION OF THE ANIMAL

(1) Internal fat depots

Correlations were calculated between the weight of omental and mesenteric fat and combinations of these fats and estimates of carcass fatness for the 48 ewes from PART I. The mean weight of omental fat was 3.83 lb. (range 1.50 - 7.10 lb.) The mean weight of mesenteric fat was 1.54 lb. (range 0.94 - 2.28 lb.)

Table 83

Correlation coefficients estimated between weight of some internal fat depots and estimates of carcass fatness for 48 ewes.

	Carcass chem. fat, lb.	Leg + loin dissected fat g.	Carcass % chem. fat	Omental fat lb.
Omental fat lb.	0.7821 ss	0.6905 ss	-	-
Mesenteric fat lb.	0.5742 ss	-	-	0.7061 ss
Omental + mesenteric fat lb.	0.7751 ss	-	0.6177 ss	-

Since weight of omental fat and weight of carcass fat were most highly correlated, a regression equation was calculated for estimating carcass fat weight.

Carcass fat weight (lb.) = 10.36 + 3.745X where X = weight of omental fat (lb.) $S_{y.x}$ = 3.89 lb. It can be seen that the above estimate of carcass fatness is less accurate than the more easily obtained information on the carcass as a whole for

which results are presented in Table 86.

(2) Information from the internal organs.

The results of an experiment by Kraybill et al. (1954) suggested that lean body mass could be estimated accurately from the weight of some internal organs. In this case it would also be possible to estimate fat by difference. Data were available from 48 experimental ewes (PART I) to test these relationships. It should be borne in mind that all the variables to be used were affected by the low plane of nutrition and/or thyroxine treatments.

Table 84

Correlations between some internal organ weights and the weight of the fat free carcass, carcass weight, weight of muscle from the leg + loin, and carcass protein weight, for 48 ewes.

	Liver wt.		Kidneys wt.		Heart wt.	
Carcass wt.	0.4394	ss	-		-	
Fat free carcass wt.	0.7291	ss	0.4675	ss	0.4540	ss
Leg + loin muscle wt.	0.6695	ss	-		-	
Carcass protein wt.	0.5278	ss	-		-	

As all the organs considered above and the fat free carcass weight were reduced by a low plane of nutrition the correlations between these variables were recalculated within the classification of nutritional plane.

Table 85

Correlations between the weight of the fat free carcass and organ weights calculated within the nutritional planes.

Wt. of fat free carcass	Liver wt.		Kidneys wt.		Heart wt.	
25 Normal plane ewes	0.6690	ss	-0.0448	ns	0.1589	ns
23 Low plane ewes	0.2574	ns	0.2054	ns	0.5079	s

These results indicate that within a uniform group of mature ewes, organ weights are unlikely to be of use for predicting carcass weight and composition. Of the organs tested, liver weight was most closely related to fat free carcass weight.

CHAPTER V

DISCUSSION

The ewes were selected in Part 1 on the assumptions that animals of equal body and carcass weights should be of approximately equal fatness. The correlation coefficients of 0.71 and 0.91, between carcass fat weight and body and carcass weights respectively, provides some justification for these assumptions. The above correlations indicate that level of carcass fatness is likely to be the major factor influencing body and carcass weight.

The accuracy of prediction of chemical carcass fat from indices of carcass composition is suggested in Table 86 and for dissectible carcass fat in Table 87.

Table 86

Standard errors of estimate of regression equations for predicting chemical carcass fat. (48 carcasses.)

Independent variate = X	Standard error (% chemical fat)
% carcass water	1.20%
% chemical fat of rib cut	1.72%
% water of rib cut	2.19%
Carcass specific gravity	2.85%
Dressing percentage	3.20%
Carcass weight	4.20%
Weight of omental fat	6.44%

Table 87

Standard errors of estimate of regression equations for predicting dissectible carcass fat. (25 carcasses - stored data.)

Independent variate = X	Standard error (% dissectible fat+)
Wt. dissectible fat in leg+loin	2.38%
Wt. dissectible fat in the loin	2.94%
Carcass wt.	4.49%

+The standard error was originally expressed as weight of fat, but was converted to percentage fat in the carcasses (for comparative purposes) by using mean carcass weight.

Although, percentage carcass water and percentage water in the rib cut are among

the most accurate indices for the prediction of carcass chemical fat percentage, they are unlikely to be used in practice. In view of the work involved in obtaining these figures, the added chemical work necessary to get percentage carcass fat figures is small and greater accuracy will be achieved.

Thus the two most accurate indices of carcass fat which are likely to be used in practice are percentage chemical fat in the rib cut and weight of dissected fat in the leg plus loin (g.). The above comparison will be unfair to the leg plus loin in that smaller numbers were used in this regression equation. Also, the weight of fat dissected will include varying proportions of chemical fat; so these two sample regions are not being strictly compared on the same basis. It should be noted that these indices were estimated from different population samples.

Because of the saving in time and finance by using indices on the carcass as a whole, the comparative accuracy of these indices and in particular of carcass specific gravity makes them worthy of consideration. The relative accuracy of carcass weight as an index of carcass fat proportion provides a justification for taking carcass weight as an end point in production experiments for the mature ewe. However, data are needed on the other sexes (male and neuter), on the growing sheep, and on other species before wide generalisations can be made. The indices from the internal fat depots looked at, do not appear to be of practical use in the mature ewe.

As has been shown for other species and for preliminary results in the lamb, the specific gravity technique gives a good indication of the fat content of mature ewe carcasses. Underwater weighing indicated a carcass specific gravity ranging from 1.009 to 1.054 for carcass fat percentages ranging from 24.9 to 54.5.

On these ewe data, no greater accuracy of prediction was obtained by fitting a hyperbolic curve, which for theoretical reasons should be more accurate (Morales et al., 1945) than a straight line.

The equation for the 15 control sheep presented here differs from that reported

previously for these same ewes (Barton and Kirton, 1956) because the present equation was calculated on the corrected % ether-extract (fat) whereas the previous equation was based on the uncorrected % ether-extract.

The statistical estimation of the specific gravity of fat and the specific gravity of the fat free carcass agreed well with the actual determination of the former specific gravity and results published in the literature for the specific gravity of the fat free animal body. The evidence of Rathbun and Pace (1945) on guinea pigs suggest that these ewe carcass specific gravity values may apply to the ewe body as a whole; direct determination is however necessary to validate this extrapolation.

The specific gravities of the joints studied gave a good indication of their state of fatness. However, in view of the high relationships between state of fatness of these joints and carcass fatness, the corresponding correlations between specific gravities of these joints and of the carcasses were disappointingly low.

The magnitude of the correlation between dressing percentage and carcass fatness was surprising in view of the diversity of treatments applied to the experimental groups and the two different lengths of pre-slaughter starvation period. This suggests that under standard conditions and using a standard basis for calculating dressing percentage, this percentage can give a useful measure of fatness.

The 9-10-11 rib cut has proved in the sheep, as for cattle, to be a reliable sample joint as an indicator of carcass chemical composition. From this cut, the chemical fat and water composition of the complete carcass could be accurately estimated. The rib cut gave a less reliable estimate of carcass protein. No ash data were available on the rib cut.

The omental and mesenteric fat depots, individually and in combination, were related to level of carcass fatness. This relationship was not, however, good enough for experimental predictive purposes.

The low order of the correlation between internal organ weights and the weights

of the chemical fat free carcass, protein and muscular tissue suggest that this relationship is not high enough for predictive purposes in mature ewes. The high correlations reported by Kraybill *et al.* (1954) were calculated on cattle of widely different ages and liveweights. On animals of more uniform age and weight the correlations were of a lower order as was found in this present study on mature ewes. The liver weight appeared to be most closely related to fat free body weight but even for this organ the relationship was not close.

CHAPTER VI

SUMMARY AND CONCLUSIONS

(1) The carcasses of 48 Romney crossbred ewes studied in PART I plus stored dissection data on a further 25 Romney crossbred ewe carcasses were used in an investigation of the value of indices of carcass composition.

(2) High correlation coefficients of 0.91 and 0.94 were estimated between carcass weight and weight of chemical carcass fat and fatty tissue respectively, indicating that this tissue is a major factor influencing carcass weight in the mature ewe. Thus with this knowledge there is some justification for taking carcass weight as an index of treatment effects in this species.

(3) The use of carcass specific gravity as an index of carcass fatness has been validated for the ewe as has previously been done for other species. The mean carcass specific gravity was 1.029 (range 1.009 - 1.054) for 48 ewe carcasses averaging 40.4% chemical fat (range 24.9 - 54.3%) and the correlation between them was -0.84. Regression equations are presented for predicting carcass fat and $\frac{484.0}{S.G.} - 428.9$ is suggested for estimating the carcass fat percentage of New Zealand Romney-crossbred ewes from carcass specific gravity. Joint specific gravity was also closely related to the fatness of the joints studied.

(4) Dressing percentage was also closely related to state of carcass fatness, but is slightly less accurate for prediction of chemical fat than is carcass specific gravity.

(5) The use of a 9-10-11 rib cut has been studied for the first time as an index of the chemical composition of mutton carcasses. This cut is an accurate estimator of total carcass fat and water percentages, but is a less accurate indicator of carcass protein percentage.

(6) The use of the leg plus loin as sample joints gave reliable indications of

carcass fatty and muscular tissue which was similar to the results reported by other workers on the pig and immature sheep.

(7) Carcass water percentage was closely related to carcass chemical fat percentage ($r = 0.98$).

(8) The weights of omental and mesenteric fat were highly significantly correlated with the weight of carcass fat, but the relationship was not close enough to be useful for predictive purposes.

(9) The relationships between selected organ weights (liver, kidneys, heart) and the weight of the fat free carcasses were too weak for predictive purposes in the mature ewe.

BIBLIOGRAPHY

Andrews, F.N., and Whaley, R.M. (1954). Unpublished manuscript.

Anon, (1956). Editorial. Farming News and North British Agriculturalist. Vol. CVII, No. 42, Oct. 13.

Ashworth, U.S., and Cowgill, G.R. (1938). J. Nutr. 15:73.

Aunan, W.J., and Winters, L.M. (1949). J. Anim. Sci. 8:182.

Aunan, W.J., and Winters, L.M. (1952). J. Anim. Sci. 11:319.

Babineau, L., and Pagé, E. (1955). Canad. J. Biochem. Physiol. 33:970.

Balch, C.C., Balch, D.A., Bartlett, S., Johnson, V.W., and Rowland, S.J. (1952). Brit. J. Nutr. 6:356.

Barnicoat, C.R., and Shorland, F.B. (1952). N.Z. J. Sci. Tech. (A) 33:(5) 16.

Barton, R.A., and Kirton, A.H. (1956). Nature (Lond.) 178:920.

Bate-Smith, E.C. (1942). Chem & Ind. 61:373.

Behnke, A.R., Feen, B.G., and Welham, W.C. (1942). J.A.M.A. 118:495. (Cited Kraybill et al. 1952).

Behnke, A.R. (1945). Medicine 24:359. (Cited Kraybill et al. 1952).

Blaxter, K.L. (1945). J. Endocrin. 4:237 and 4:266.

Blaxter, K.L. (1948). J. Agric. Sci. 38:1.

Blaxter, K.L. (1948a). J. Agric. Sci. 38:20.

Blaxter, K.L., Reineke, E.P., Crampton, E.W., and Petersen, W.E. (1949). J. Anim. Sci. 8:307.

Breidenstein, B.C., Bull, S., Forbes, R.M., and Stouffer, J.R. (1955). J. Anim. Sci. 14:1227.

Brody, S. (1945). Bioenergetics and Growth. Reinhold Publishing Corporation, New York.

Bronte-Stewart, B., Antonis, A., Eales, L., and Brock, J.F. (1956). Lancet 270:523.

Brown, C.J., Hillier, J.C., and Whatley, J.A. (1951). J. Anim. Sci. 10:97.

Butler, G.W. (1957). Personal communication.

Callow, E.H. (1942). Chem. & Ind. 61:381.

Callow, E.H. (1944). J. Agric. Sci. 34:177.

Callow, E.H. (1947). J. Agric. Sci. 37:113.

Callow, E.H. (1948). J. Agric. Sci. 38:174.

Callow, E.H. (1949). J. Agric. Sci. 39:347.

Callow, E.H. (1950). J. Agric. Sci. 40:1.

Cameron, A.T., and Carmichael, J. (1921). J. Biol. Chem. 46:35.

Clarke, E.A., and McMeekan, C.P. (1952). N.Z. J. Sci. Tech. (A) 33:(5) 1.

Cover, S., Mackey, A.K., Murphey, C.E., Miller, J.C., Bass, H.T., Bell, C.L., and Hamalainen, C. (1944). Texas Agric. Expt. Sta. Res. Bul. 661.

Cresswell, E. (1957). Personal communication.

DaCosta, E., and Clayton, R. (1950). J. Nutr. 41:597.

Dibble, J.H. (1932). J. Path. Bact. 35:451. (Cited Keys et al. 1950).

Drill, V.A., and Shaffer, C.B. (1942). Endocrin. 31:567.

Franklin, M.C. (1952). Aust. J. Agric. Res. 3:168.

Fredeen, H.T., Bowman, G.H., and Stothart, J.G. (1955a). Canad. J. Agric. Sci. 35:91.

Fredeen, H.T., Bowman, G.H., and Stothart, J.G. (1955b). Canad. J. Agric. Sci. 35:95.

Frens, A.M. (1949). Landbouwk. Tijdschr. 61:916.

Green, W.W. (1954). J. Anim. Sci. 13:61.

Hammond, J. (1932). Growth and Development of Mutton Qualities in the Sheep. Oliver and Boyd, Edinburgh.

Hankins, O.G., and Titus, H.W. (1939). U.S.D.A. Yearbook of Agriculture. Food and Life. p.450.

Hankins, O.G., Knapp, B., and Phillips, R.W. (1943). J. Anim. Sci. 2:43.

Hankins, O.G., and Howe, P.E. (1946). U.S.D.A. Tech. Bul. 926.

Hankins, O.G. (1947). U.S.D.A. Tech. Bul. 944.

Hankins, O.G. (1953). Proc. 6th Ann. Recip. Meat Conf. Chicago. p.131.

Hart, D.S. (1955). Proc. N.Z. Soc. Anim. Prod. 15th Ann. Conf. p.57.

Hazel, L.N., and Kline, E.A. (1952). J. Anim. Sci. 11:313.

Henneman, H.A., Reineke, E.P., and Griffin, S.A. (1955). J. Anim. Sci. 14:419.

Hiner, R.L. (1957). Personal communication.

Hix, E.L., Evans, L.E., and Underbjerg, G.K.L. (1953). J. Anim. Sci. 12:459.

Hix, E.L., Underbjerg, G.K.L., and Hughes, J.S. (1956). Unpublished manuscript.

Hopper, T.H. (1944). J. Agric. Res. 68:259.

Ivy, A.C. (1930). Physiol. Rev. 10:282.

Jackson, C.M. (1915). Amer. J. Anat. 18:75. (Cited Keys et al. 1950).

Jordan, R.M. (1954). J. Anim. Sci. 13:438.

Karp, A., and Stetten, D. (1949). J. Biol. Chem. 179:819.

Kennelly, B., and Maynard, L.A. (1953). J. Nutr. 49:599.

Keys, A., Brožek, J., Henschell, A., Mickelsen, O., and Taylor, H.L. (1950). The Biology of Human Starvation. University of Minnesota Press.

Keys, A., and Brožek, J. (1953). Physiol. Rev. 33:245.

Keys, A. (1956). Lancet 270:576.

Kline, E.A., Ashton, G.C., and Kastelic, J. (1955). J. Anim. Sci. 14:1230.

Kraybill, H.F., Hankins, O.G., and Bitter, H.L. (1951). J. Appl. Physiol. 3:681.

Kraybill, H.F., Bitter, H.L., and Hankins, O.G. (1952). J. Appl. Physiol. 4:575.

Kraybill, H.F., Goode, E.R., Robertson, R.S.B., and Sloane, H.S. (1953). J. Appl. Physiol. 6:27.

Kraybill, H.F., Hiner, R.L., and Farnworth, V.M. (1954). J. Anim. Sci. 13:543.

Lawes, J.B., and Gilbert, J.H. (1859). Philos. Trans. pp.494 - 680. (Cited Callow 1944)

Lesser, G.T., Blumberg, A.G., and Steele, J.M. (1952). Amer. J. Physiol. 169:545. (Cited Keys and Brožek, 1953).

Lofgreen, G.P., and Garrett, W.N. (1954). J. Anim. Sci. 13:496.

Lush, J.L. (1926). J. Agric. Res. 32:727.

McMeekan, C.P. (1940). J. Agric. Sci. 30:276.

McMeekan, C.P. (1941). J. Agric. Sci. 31:1.

McMeekan, C.P. (1942). N.Z. J. Sci. Tech. (A) 23:330.

McNally, E.H. (1955). Poultry Sci. 34:152.

Merritt, F. (1954). Proc. 17th Ann. Mtg. Sheepfarmers, Massey Agricultural College, p.97.

Meyer, J.H., Lueker, C.E., and Smith, J.D. (1956). J. Nutr. 60:121.

Morales, M.F., Rathbun, E.N., Smith, R.E., and Pace, N. (1945). J. Biol. Chem. 158:677

Morgulus, S. (1923). Fasting and Nutrition. Dutton, New York. (Cited Keys et al. 1950).

Moulton, C.R., and Trowbridge, P.F. (1921). Mo. Agr. Expt. Sta. Res. Bul. 43. (Cited Hopper, 1944).

Moulton, C.R., Trowbridge, P.F., and Haigh, L.D. (1922). Mo. Agr. Expt. Sta. Res. Bul. 54. (Cited Hopper, 1944).

Moulton, C.R., Trowbridge, P.F., and Haigh, L.D. (1922a). Mo. Agr. Expt. Sta. Res. Bul. 55. (Cited Hopper, 1944).

Moulton, C.R. (1923). J. Biol. Chem. 57:97.

Moulton, C.R., Trowbridge, P.F., and Haigh, L.D. (1923a). Mo. Agr. Expt. Sta. Res. Bul. 61. (Cited Hopper, 1944).

Murray, A.J. (1922). J. Agric. Sci. 12:103.

New Zealand Meat Producers Board 34th Ann. Rept. (1956).

Owen, E.C. (1948). Biochem. J. 43:243.

Owen, E.C. (1948a). Biochem. J. 43:255.

Pace, N., and Rathbun, E.N. (1945). J. Biol. Chem. 158:685.

Pálsson, H. (1939). J. Agric. Sci. 29:544.

Pálsson, H., and Vergés, J.B. (1952). J. Agric. Sci. 42:1 & 42:93.

Pearson, A.M., Bratzler, L.J., Deans, R.J., Price, J.F., Hoefer, J.A., Reineke, E.P., and Luecke, R.W. (1956). J. Anim. Sci. 15:86.

Pfeiffer, L. (1887). Z. Biol. 5. (New Series), p.340. (Cited Keys et al. 1950).

Pharazyn, C. (1884). Article in N.Z. Times (Wellington), Jan. 24, 1884. (Cited Supplement to the Press, Christchurch, Feb. 15, 1957, p.1.)

Pomeroy, W.R. (1941). J. Agric. Sci. 31:50.

Pomeroy, W.R. (1956). Agric. Rev. (Lond.) 2: No. 7. p.35.

Préobrajensky, B.S., and Baranova, L.I. (1932). Acta oto-laryng. 18:1. (Cited Keys et al. 1950).

Rathbun, E.N., and Pace, N. (1945). J. Biol. Chem. 158:667.

Reed, L.L., Anderson, W.E., and Mendel, L.B. (1932). J. Biol. Chem. 96:513.

Reid, J.T., Wellington, G.H., and Dunn, H.O. (1955). J. Dairy Sci. 38:1344.

Robinson, P. (1948). J. Agric. Sci. 38:345.

Roche, J., and Michel, R. (1955). Physiol. Rev. 35:583.

Seath, D.M., Branton, C., and Groth, A.H. (1944). J. Dairy Sci. 27:641.

Seath, D.M., Branton, C., and Groth, A.H. (1945). J. Dairy Sci. 28:509.

Sedlmair, A.C. (1899). Z. Biol. 37:25. (Cited Keys et al. 1950).

Shorland, F.B., de la Mare, P.B.D., Sorrell, D.M.P., and Barnicoat, C.R. (1947). N.Z. J. Sci. Tech. (A) 29:76.

Shorland, F.B. (1957). Personal communication.

Smith-Pilling, S.H., and Barton, R.A. (1954). N.Z. J. Agric. 88:98.

Snedecor, G.W. (1946). Statistical Methods. Iowa State College Press, Ames, Iowa.

Stouffer, J.R. (1955). Proc. 8th Ann. Recip. Meat Conf. Chicago, p.87.

Trowbridge, P.F., Moulton, C.R., and Haigh, L.D. (1915). Mo. Agr. Expt. Sta. Res. Bul. 18. (Cited Hopper, 1944).

Trowbridge, P.F., Moulton, C.R., and Haigh, L.D. (1918). Mo. Agr. Expt. Sta. Res. Bul. 28. (Cited Hopper, 1944).

Turner, C.W., and Reineke, E.P. (1946). Mo. Agr. Expt. Sta. Res. Bul. 397.

Wallace, L.R. (1948). J. Agric. Sci. 38:245.

Warwick, E.J., Childs, E.C., Flower, A.E., and Ham, W.E. (1948). J. Anim. Sci. 7:198.

Wellington, G.R., Reid, J.T., Bratzler, L.J., and Miller, J.I. (1956). J. Anim. Sci. 15:76.

White, R.R., Christian, K.R., and Williams, V.J. (1956). N.Z. J. Sci. Tech. (A) 38:440.

Whiteman, J.V., Hillier, J.C., and Whatley, J.A. (1951). J. Anim. Sci. 10:658.

Whiteman, J.V., Whatley, J.A., and Hillier, J.C. (1953). J. Anim. Sci. 12:859.

Widdowson, E.M., and McCance, R.A. (1956). Brit. J. Nutr. 10:363.

Wilder, C.P. (1955). Proc. 8th Ann. Recip. Meat Conf. Chicago, p.138.

APPENDIX

A copy of all the data used in this thesis has been lodged with the Sheep Husbandry Department, Massey College.

APPENDIX

Theoretical method of estimating the density of fat and the density of the fat free body as suggested by Dr. W. Harvey, Biometrition, Beltsville. (Hiner, 1957. Personal communication).

Two least squares methods are available for estimating D_L and D_F from data such as that given by Kraybill et al. (1952). The linear regression equations which may be used to estimate these two densities are derived from the theoretical equations given by Kraybill et al. on page 579 of the paper referred to above. The derivation of both equations was given by Hiner but only the derivation of equation (2) which it was considered gave the best estimates of D_L and D_F will be given below. This equation was applied to the data in the present experiment.

Theoretical equation

$$G = \frac{M}{\frac{F}{D_F} + \frac{M-F}{D_L}}$$

Where G = whole-animal specific gravity
M = body weight
F = weight of body fat
D_F = density of body fat
D_L = density of lean or fat-free body mass.

For the purposes of the present experiment where appropriate read carcass for body and specific gravity for density. This equation expresses a curvilinear relationship between body fat and body specific gravity.

Derivation of equation (2)

Divide the numerator and denominator of the theoretical equation by M.

$$G = \frac{1}{\frac{F_d}{D_F} + \frac{1-F_d}{D_L}}$$

where F_d is the decimal fat percentage

$$\frac{1}{G} = \frac{F_d}{D_F} + \frac{1-F_d}{D_L}$$

$$= \frac{D_L - D_F}{D_F D_L} F_d + \frac{1}{D_L}$$

$$F_d = \frac{D_L - G}{G\,D_L} \cdot \frac{D_F\,D_L}{D_L - D_F}$$

$$= \left(\frac{D_L}{G} - 1\right) \left(\frac{D_F}{D_L - D_F}\right)$$

$$= \frac{D_F\,D_L}{D_L - D_F} \quad \frac{1}{G} \frac{DF}{D_L - D_F} \qquad (2)$$

This is now in the form of the ordinary linear regression equation,

$$y = a + b\,X$$

where: $y = F_d$

$$X = \frac{1}{G}$$

$$a = \frac{D_F}{D_L - D_F}$$

$$b = \frac{D_F\,D_L}{D_L - D_F}$$

In both equation (1) and equation (2), X was measured with error. However, the error of measuring X was likely to be greater if equation (1) was used. Therefore, it would seem that the best estimate of D_L and D_F are obtained from the application of equation (2) given above.

Equation (2) corresponds to the equation fitted by Kraybill *et al.* (1952).