A STUDY OF THE GROWTH AND CARCASS CHARACTERISTICS OF RANGY AND SHORT TYPE STEERS OF THE ANGUS, BEEF SHORTHORN AND HEREFORD BREEDS

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ABSTRACT

The growth rate and carcass characteristics of rangy and short conformation types of steers in Angus, Hereford and Beef Shorthorn breeds were compared in two trials (Trials X and XI) at Massey University.

Rangy and short type weaner steers were chosen on the basis of visual assessment of conformation by experienced stockmen. The Angus steers in Trial X came from the one herd as did the Hereford steers in Trial XI. The two types of Angus (Trial XI) and Beef Shorthorn (Trial X) steers were bred in four different herds. Types within a breed were chosen by the same people, but different persons selected the representative steers in each breed.

The steers were grazed together at pasture (except for a short period on a wintering yard in their second year of life) and weighed "full" at various intervals.

They were slaughtered at an age of about 30 months. They were processed according to normal commercial practice and various aspects of carcass yield, composition and data on carcass weight, grade, fat colour, and chiller shrinkage were collected, various carcass measurements were taken and the weights of fat and bone were recorded for the right side quarters of each carcass.

Fifteen steers were purchased of each type. Trial X concluded in March 1976 (after a period of 625 days) with 13 rangy and 14 short Angus steers, and 14 rangy and 15 short Beef Shorthorn steers. There were no animal losses in Trial XI (633 days) which finished in April 1977 (with 15 steers in each type group) in which the two types in the Angus and Hereford breeds were compared.

The results were analysed within trials by the fitting constants procedure using fixed-effects linear models. Type effects were compared within each breed group. One model included the right side of the cold carcass as a covariate for some aspects of the carcass data analysed within a breed.

Rangy type steers in each breed had heavier initial and final liveweights and carcass weights than short type steers. Rangy steers grew more rapidly than short steers in three of the four comparisons. There was no significant difference in growth rate between types of Angus steers in either trial. Rangy Angus steers gained 0.02 kg/day (n.s.) more than short Angus steers in Trial X, but the short steers grew faster in Trial XI, 0.03 kg/day (n.s.) and they may have exhibited compensatory growth in the first half of the trial. Rangy Beef Shorthorn and Hereford steers showed a greater superiority in growth rate (Beef Shorthorn 0.07 kg/day, $P<0.001$; Hereford 0.06 kg/day, $P<0.001$), compared with short type steers of these two breeds.

These differences are important advantages in beef production, however the large difference in growth rate meant that because all steers were slaughtered at the same time (to meet the experimental design) the faster-growing Beef Shorthorn and Hereford steers were carried to much heavier weights than would be normal in most farming situations and this adversely affected their carcass composition, because of higher proportions of fat resulting from their heavier carcass weights.

An analysis of the order in which steers were slaughtered showed that they moved into the stunning box independent of their type, breed group or liveweight. This finding indicated that data collection subsequent to the processing of the carcasses or in the boning-out of the quarters would be spread across types and breeds randomly.

There were very small, non-significant differences between types in dressing-out percentage, carcass shrinkage in the chiller overnight (by weight, or as a percentage of hot carcass weight), and between the weight of the right and left sides of the carcass. This meant that the types tended to rank in the same order if their mean carcass composition was expressed on either a right side, cold or hot carcass basis, or liveweight basis.

Preliminary statistical analysis showed there was little difference between types in the distribution of trimmed, boneless lean, bone and trimmed-off fat between the forequarters and hindquarters of the right sides. Therefore the data for each quarter were pooled and the composition of the right side of each carcass was compared between types.

Rangy steers yielded a greater weight of trimmed, boneless lean and bone in each breed group. They yielded a lower weight of excess fat in Angus steers, but not in Beef Shorthorn or Hereford steers.

There were small, inconsistent differences between types in the percentage of commercially trimmed boneless lean and bone, but larger differences in the percentage of excess fat trimmed from the right side of the carcass. The size of the type differences was influenced by right side weight.

The ratio of trimmed meat to bone did not differ significantly between types, therefore it was concluded that the main determinant of the differences in the percentage yields was the amount of excess trimmed fat.

Rangy steers tended to have a lower percentage of excess fat and were leaner than short steers except in the case of the Beef Shorthorns and Herefords.

Angus types had similar amounts of kidney and channel fat (no significant difference between types in Trials X and XI, respectively). Rangy steers had more kidney and channel fat than short steers in Beef Shorthorns (1.73 kg, $P < 0.05$) and Herefords (2.22 kg, $P < 0.01$). When adjusted for right side weight there was less kidney and channel fat in rangy than short Angus (0.72 kg, n.s. Trial X, 1.72 kg, $P < 0.05$ Trial XI) and Beef Shorthorns (0.53 kg, n.s.), but slightly more in rangy Herefords (0.53 kg, n.s.). Rangy Angus (Trial X) and Beef Shorthorn steers had less fat over the 12th ribeye than short steers (2.0 and 1.5 mm, n.s., respectively). There was little difference in fat depth between Angus (Trial XI) and Hereford types (0.6 and 0.8 mm, n.s., respectively).

When the depth of fat over the ribeye of the 12th rib was adjusted for right side weight short steers had a slightly greater depth of fat than rangy steers in Angus (2.5 mm, n.s.) and Beef Shorthorns (5.1 mm, n.s.) in Trial X. However in Trial XI rangy Angus steers had a slightly greater depth of fat than short steers (0.4 mm, n.s.), but there was no difference between types in Herefords.

Rangy steers had larger ribeyes than short steers except in Herefords. The difference in ribeye areas between types was

2.51 cm^2(n.s.) in Angus Trial X, 6.77 cm^2($P<0.01$) in Beef Shorthorns and 5.81 cm^2($P<0.05$) in Angus Trial XI. Short Hereford steers had larger ribeye areas than rangy steers by 3.77 cm^2(n.s.). These differences were reduced and became non-significant when adjusted for right side weight except in Herefords where short steers had significantly largerribeyes (6.76 cm^2, $P<0.01$).

Rangy steers had longer carcasses than short steers and longer bone measurements. They had a deeper carcass than short steers in Beef Shorthorn and Hereford steers, but not in Angus steers. The measurement of the depth of the carcass was influenced by fatness which appeared visually to increase the depth of short carcasses in relation to their skeletal size. The types did not differ in the ratio of carcass length to carcass depth.

When carcass dimensions were adjusted for right side weight the differences between types generally became non-significant except in Beef Shorthorn cattle. Rangy steers had slightly greater measures of carcass length, length of the leg and forearm, but had shorter measures of carcass depth than short-type steers except in Beef Shorthorns although the differences were not large.

It was concluded that selection of rangy- compared to short-type weaner steers by visual assessment of conformation resulted in more beef being produced by the Angus, Hereford and Beef Shorthorn cattle. The reasons for increased production were various. In each comparison between types the superior initial weight of rangy weaner steers contributed about half of the increase in final yield of lean (assuming a similar composition at weaning).

Rapid growth rate of rangy steers in Beef Shorthorn and Herefords contributed to their increased yield of lean although they were over-finished as a consequence of their greater growth rate and the experimental design requiring all cattle to be slaughtered at one time.

Growth rate was not found to be an important factor in Angus steers where it appeared that a small superiority in carcass composition resulted in a greater yield of lean meat from rangy steers.

Analysis of carcass composition and dimensions at slaughter showed considerable variation within each type. Ratios of body length to depth did not differ and in this respect rangy steers were "bigger" and heavier than short steers though not disproportionately so in relation to weight. The variation within each type suggested that some steers would have been classified into the other group had this been done at the conclusion of the trial. The ratio of body length to chest depth is not a true measure of skeletal size because of the influence of carcass fat in measuring chest depth. It would thus be unwise to draw conclusions about proportionality in size from this study.

The experiment has indirectly shown the importance of a heavy weaning weight, of rapid growth rate, and of lean content in beef production. The relative importance of other factors such as age, pre-weaning growth rate, sire and dam and the pre-trial environment could not be assessed with the cattle purchased for this investigation.

Visual assessment was not consistent in terms of selection for the same trait. This may have been due to the effect of different

persons (between breeds) and their interpretation of "types" and to the amount of phenotypic variation for type in the population from which the steers were selected.

The trends observed in this study are in the right direction to improve beef production of traditional beef breeds. The concept will be of use to farmers and others who choose cattle with or without records.

The carcasses were graded either P1 or G in both trials. The number of carcasses in each grade were: Trial X G=33, P1=23; Trial XI G=16, P1=44. An analysis tested the hypothesis that there were no differences between grades in carcass characteristics. Carcasses graded G were heavier (15.4 kg, $P < 0.05$) in Trial X, but not significantly so in Trial XI (7.9 kg, n.s.). They had no more kidney and channel fat (1.10 kg, n.s., Trial X and 0.56 kg, n.s. Trial XI) than carcasses graded P1. Results for other carcass characteristics were inconsistent between trials. Carcasses graded G in Trial X had a greater depth of fat over the 12th ribeye (2.4 mm, $P < 0.05$), and a greater proportion of excess fat and less trimmed lean of the right side of the carcass (2.26% fat, $P < 0.001$, and 1.58% lean, $P < 0.05$). These results agree with grade expectations. In Trial XI however, carcasses graded G had the same fat depth over the 12th ribeye (0.0 mm, n.s.), less excess fat trim and more lean as a percentage of right side weight (1.74% fat, $P < 0.01$, 1.72% lean, $P < 0.05$) in direct contradiction to the results of Trial X and of grade expectations.

Subjective visual assessment of fat depth from the uncut surface

of the carcass resulted in 60 and 88 percent of carcasses being wrongly classified in relation to G grade standards (Trials X and XI, respectively). Graders had more success in classifying "leaner" carcasses 30 and 25 percent of carcasses graded P1 had fat depths outside the grade specification (Trials X and XI, respectively) and then by only a few millimetres. Carcasses graded G in Trial X were of a similar "size" to those graded P1, but were heavier, whereas in Trial XI carcasses graded G were "larger", but of a similar weight.

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CHAPTER ONE

INTRODUCTION

The shape or conformation of a beef steer is considered by many stud breeders and commercial producers to be of importance as an indicator of carcass and meat quality attributes and possibly growth potential.

Traditionally the ultimate body shape of a beef animal was considered to be one which was short and blocky, deep, well let down in the crutch, with a wide, full brisket and a wide and level back and loin. This was the general shape of the British beef breeds which were said to have superior conformation relative to "unimproved" breeds. It was believed that such cattle would yield more red meat, have a higher ratio of meat to bone, and in particular have more weight in the region of the high-priced cuts than other conformation types.

There is now a great deal of objective evidence which shows that cattle of the short, blocky shape do not excel in beef production. They tend to grow slowly and are early maturing, that is, they lay down large amounts of carcass fat at relatively light carcass weights. Blocky cattle may have a higher muscle to bone ratio than other types probably reflecting early carcass maturity, but this is achieved at high levels of fatness. It is now understood that there are relatively small differences in muscle distribution even between breeds of widely differing shapes.

Shape must be considered within the boundary of functional efficiency for beef production. In one extreme, selection for short, blocky types resulted in an increase in the frequency of dwarf cattle, a genetic condition associated with compact or comprest types. These dwarfs never grew to a marketable product. In the other extreme, selection for muscularity could increase the incidence of double-muscled cattle which experience many problems including those of locomotion and reproduction. These types do not contribute to beef production and therefore should be avoided by genetic selection.

In demonstrating that short, blocky cattle do not excel in beef production, it was shown that rangy types tended to grow more rapidly and produce heavy carcasses yielding a higher proportion of lean meat. This has led to the promotion of long, rangy muscular shapes for beef production.

Some research workers have challenged this approach. Berg and Butterfield (1976) state: "Advocates of live judging, recognising that short and deep have proven wrong have now jumped on terms such as long and stretchy, particularly in the loin and rump regions of the high-priced cuts. There is no evidence in favour of length as an indicator of merit and there is no evidence that disproportionate length in the high-priced regions will be beneficial".

Barton (1971b) suggested that stretch and substance and heavy muscling were required in modern cattle and described methods of evaluating muscle development in the live steer.

Very few studies have evaluated the importance of lean, muscular shapes within a breed. Present understanding of the relationship between shape and carcass composition is mainly based on studies in which differences in shape are confounded by between breed differences in growth and carcass composition. It is known that there are differences between breeds in growth rate and hence size and weight, in muscle to bone ratio, small differences in muscle distribution and larger differences in the amount and distribution of carcass fatness. Not all of these differences can be explained in terms of relative maturity.

It follows that the determinants of shape between breeds are not necessarily the same as those which determine shape within a breed. This means that it is important to investigate the effect of shape within a breed, a subject which has received only passing attention in research.

The objectives of this present study were to compare the growth performance and carcass characteristics of two different body types of steers within each of the Angus, Hereford and Beef Shorthorn breeds. Aspects of meat quality were also studied, but are not reported here.

Short and blocky types in each breed were compared with rangy types in two experiments which concluded in 1976 and 1977.

The results will be of considerable interest to breeders and producers of these three beef breeds in New Zealand. The outcome of this work should result in the adoption of a relatively simple selection criterion for shape which can be used in conjunction with performance recording, thereby hopefully increasing the production of leaner beef.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 The importance of shape in beef production

Visual appraisal of cattle has two aims; one relates to how well the animal will function, breed, graze and survive (these are important considerations but are not the concern of this review), the other relates to the kind of carcass which will be produced (Berg and Butterfield, 1976). This present review is concerned with the relationship between shape and carcass composition (generally known as conformation, Barton 1967), the quantity and distribution of meat in the carcass.

This is an important subject which has been overemphasized in the past - relative to more direct measures of beef production - in the historical approach to live animal shape (Barton, 1965, 1967; Preston and Willis, 1974). Nevertheless it demands some consideration in modern systems of beef production (Harrington, 1971; Kauffman, Grummer, Smith, Long and Shook, 1973; Berg and Butterfield, 1976).

An extensive review of the literature concerning the relation between live animal conformation and the carcass of cattle was made by Barton (1967) and, accordingly, need not be duplicated here. Barton's review was presented at a time when objective evaluation of carcass composition was gaining momentum. The general shape achieved by the more numerous British breeds of beef cattle (Angus, Hereford, Beef Shorthorn) was regarded as the ultimate for meat production and the characters of blockiness, compactness, depth, shortness of leg, size, levelness of topline and underline, smoothness of outline and general symmetry were considered by judges and breeders to indicate apparent meatiness (Barton 1967).

Barton found that the claims made for the traditional beef breeds were not substantiated by objective evidence, and that continued emphasis on traditional shape was not to be recommended. He concluded: "The conformation and size of cattle have been changed by selection. The [then] modern beef animal is generally smaller and more compact than formerly, but this trend has not increased the proportion of lean in the carcass or changed its distribution. Thus emphasis on conformation in the showyard has been largely misdirected .... further evidence that beef-type conformation does not produce carcasses of high cutability or beef of superior eating quality comes from the numerous studies comparing dairy-bred with beef-bred animals, or unimproved with improved cattle" (Barton 1967).

Preston and Willis (1974) have also reviewed aspects of live animal judgement including assessment of carcass composition by objective or subjective methods. Their conclusions were similar to those of Barton, although they did not cite his work. They strongly condemned the use of conformation grading of cattle especially in assessment of their genetic merit in beef improvement programmes. In citing experiments where cattle had been selected for growth performance *versus* type they found that the former out-performed those selected visually on the basis of traditional shape.

It would thus appear that emphasis on traditional conformation has little place if progress is to be made in the beef cattle industry in selecting cattle on the basis of performance records. Preston and

Willis did not however, indicate that evaluation of shape had any place at all in a beef improvement programme.

More recent considerations of the subject (Harrington, 1971; Barton, 1971b; Kauffman et al. 1973; Barton, 1975b; Berg and Butterfield, 1976) suggest a new approach to the evaluation of shape in beef steers to be used in conjunction with performance records, although there are few definitive studies in which the relative importance of shape has been determined.

The rationale for the "new" approach is as follows. It is now known that there is relatively little difference in muscle distribution between breeds, or types of cattle, which have widely different shapes (Butterfield, 1964-with Polled Hereford, Hereford, Angus, Brahman, half Brahman, and unimproved Shorthorn steers; Charles and Johnson, 1976a - with Hereford, Angus, Friesian and Charolais-cross steers; Berg and Butterfield, 1976 citing Berg and Mukhoty, 1970 - with Hereford, Shorthorn-cross, crossbred, Holstein and Jersey bulls, and Hereford, Shorthorn-cross, crossbred, Brown Swiss-crossbred and Holstein steers and Hereford and Shorthorn-cross heifers; Berg, Andersen and Liboriussen, 1978a,b - with Simmental, Charolais, Danish Red and White, Romagnola, Chianina, Hereford, Blonde d'Aquitaine and Limousin cross-bred bulls).

It should not be considered that muscle weight distribution is a constant as several studies have shown that small differences exist between breeds (Mukhoty and Berg, 1973; Seebeck, 1973; Charles and Johnson, 1976a; Kempster, Cuthbertson and Smith, 1976; Truscott, Lang and Tulloh, 1976; and Berg, Andersen and Liboriussen, 1978b).

Most of these differences occur in the region of low-priced muscles of the neck and abdomen. However Truscott, Lang and Tulloh (1976) reported that Friesians had significantly greater percentages of muscle in the proximal pelvic limb and proximal thoracic limb (expensive muscle groups) than Angus with the Friesians having 1.52% more of their muscle as "expensive" muscle. Berg, Andersen and Liboriussen (1978b) found that young, lightweight Chianina bulls (at the top end) had 2.62 kg more muscle in the pistol (the region of the carcass containing most of the expensive muscles) than Hereford bulls (at the bottom end of the breeds studied).

Work by Johnson, Pryor and Butterfield (1973) indicated that differences in muscle distribution are not due to differences in the amount of intramuscular fat present.

These experiments support Butterfield's (1964) contention that selection for conformation within the beef breeds has not improved their muscle distribution. Seebeck (1973) contended that selection for muscle-weight distribution might be fruitful if a suitably precise technique of assessment could be found. However Berg, Andersen and Liboriussen (1978b) cite work by Andersen (1977) who reported the phenotypic standard deviation of pistol lean to be 2 percentage units and the heritability to be 0.29, indicating poor prospects for selection for improved muscle distribution. The fundamental question is really can we change muscle distribution without affecting functional efficiency?

Berg and Butterfield (1976) consider that the greatest contribution studies of muscle weight distribution have made is to remove a variable from the assessment of live cattle and their carcasses. The current approach to conformation attempts to assess total muscle weight rather than its distribution between high-and-low-priced regions.

Kauffman _et al_. (1973) attempted to determine the differences in composition that might be related to differences in shape. They selected 12 muscular and 12 non-muscular steers of unknown background on the basis of visual appraisal before slaughter. The muscular steers were predominantly from beef breeds and non-muscular steers from dairy breeds. Extreme differences in shape were chosen at similar levels of fatness and maturity. Muscular steers were defined as having convex bulging shapes and non-muscular steers as having concave or non-bulging shapes.

Muscular steers were 25 kg heavier (n.s.) and had a higher dressing-out % (3.1% $P < 0.01$) than non-muscular steers. Their pelvic limbs were significantly ($P < 0.05$ to $P < 0.01$) shorter, thicker, wider and more bulging than those of non-muscular steers.

There was no significant difference in the proportionality of fat-free muscles and skeletal components in the pelvic limb between the shapes. However, muscular steers had a significantly greater ratio of muscle to bone (0.8, $P < 0.05$) than non-muscular steers. The muscular steers had 1.6% more chemical fat (n.s.), 3.9% less dissectable bone ($P < 0.05$) and 2.3% more fat-free muscle in the pelvic limb. Kauffman _et al_. (1973) concluded that: "The shape of [an] animal or carcass significantly influences composition, but that the magnitude of this influence is small as compared to the effects of fatness in most cattle populations. Since extremely heavily-muscled cattle may lead to the occurence of the doubled muscled trait, caution must be exercised before excessive emphasis is given to this trait in a long range breeding program."

Perhaps these authors should have concluded that shape "reflects" composition rather than "influences" it because emphasis on shape in the past tended to the latter viewpoint. Current emphasis must use shape only as an indicator of composition in conjunction with performance records (Barton, 1975b).

Kauffman, Van Ess and Long (1976) selected five groups of steers varying in muscular shape from very angular (Longhorn), to angular, average, or bulging (Holstein, Brown Swiss, Angus, Hereford and Charolais breeds and crossbreds) and very bulging (double muscled Angus and Charolais), a total of 31 animals. The groups varied in various measures of empty body weight and carcass composition as shown in Table 2.1.

Table 2.1 Differences between steers of various shapes

Shape	Very angular	Angular	Average	Bulging	Very bulging
No. of observations	7	6	9	7	2
Live empty body weight (kg)	331	457	461	444	439
Total body fat (%)	11.2	14.1	14.6	13.5	7.6
Carcass length (cm)	117.1	127.5	121.4	119.4	115.1
Round thickness (cm)	20.8	24.7	25.0	26.9	29.0
Chuck thickness (cm)	19.6	21.5	22.6	23.4	27.5
Fat thickness at the 12th rib (cm)	0.33	0.69	1.70	1.22	0.25
loin eye area at the 12th rib (cm^2)	58.7	68.4	67.7	79.3	115.5
Dissected kidney, heart and pelvic fat (%)	4.3	4.9	3.8	3.8	2.0
Lipid-free muscle/ dissectible bone ratio of carcass	3.49	3.25	3.52	3.96	5.77

In the results presented in Table 2.1 the more muscular steers had less total body fat (excluding very angular steers) and dissected kidney, heart and pelvic fat, generally slightly shorter carcasses, thicker round and chuck measurements and larger eye muscle areas. Fat thickness increased to "average" muscling then decreased. Muscle to bone ratio increased with degree of muscling. It was also demonstrated that dressing-out percentage was significantly positively correlated to degree of muscling, but not to carcass fatness ($P<0.01$). Dressing-out percentage was negatively correlated to an estimate of thoracic cavity capacity ($r = -0.78$, $P<0.01$) and positively correlated to lipid-free muscle/bone ratio ($r = 0.79$, $P<0.01$).

Heavier-muscled cattle had higher dressing-out percentages because their body cavities were proportionately smaller. Fatter cattle did not have higher dressing-out percentages because increased quantities of mesenteric fat in the non-carcass component compensated on a proportional basis for increased quantities of fat in the carcass.

Kauffman, Van Ess and Long (1977) subsequently determined that shape *per se* did not affect feed efficiency (kg feed to produce a kg of fat-free muscle).

Caution must be exercised in interpreting the work of Kauffman and colleagues (1973, 1976, 1977) because the effect of muscular shape has been compared across breed boundaries. It is well understood that breeds differ in amount and distribution of their fat depots, in muscle to bone ratio and dressing-out percentage, as well as other aspects of composition (Preston and Willis, 1974; Berg and Butterfield, 1976; Carter, 1975; Koch and Dikeman, 1977). Thus differences in shape between breeds reflect genetic differences in compositional relationships, it has yet to be proved that the same relationship as demonstrated by Kauffman et al. (1973) holds within a breed. In addition it cannot be said that shape will be more or less relevant within, than between breeds.

Several experiments in the United States of America have reported the post-weaning growth performance, carcass composition, feed efficiency and response to different diets, carcass composition and meat quality (as well as other attributes such as pre-weaning performance and dystocia) of different "biological types" of cattle (Smith, Laster and Gregory, 1976; Smith, Laster, Cundiff and Gregory, 1976b; Koch, Dikeman, Allen, May, Crouse and Campion, 1976; Prior, Kohlmeier, Cundiff, Dikeman and Crouse, 1977; Smith, Crouse, Mandigo and Neer, 1977; Ferrell, Kohlmeier, Crouse and Glimp, 1978; Koch and Dikeman, 1977; Lipsey, Dikeman and Schalles, 1978). The biological types differ in shape, weight, and size as a consequence of the sire and dam breeds used in the experiment.

These studies are part of a long-term breed evaluation programme in which Hereford and Angus cows were mated to bulls of various breeds. For example, British beef breeds (Angus, Hereford, Shorthorn, Red Poll and South Devon) dairy breeds (Jersey, Red Dane, Milking Shorthorn and Holstein), Continental European beef breeds (Brown Swiss, Charolais, Chianina, Gelbvieh, Limousin, Maine Anjou and Simmental) and a Bos indicus breed (Brahman). The design of these experiments was presented by Smith, Laster and Gregory (1976) and varies depending on the year, and nature of the study.

In general terms these experiments have confirmed that larger, later-maturing types tend to grow more rapidly, are leaner at slaughter and produce more boneless lean meat than smaller, earlier-maturing breeds. Such differences are well known (Mason, 1971; Preston and Willis, 1974; Berg and Butterfield, 1976), but have not been demonstrated on a large scale until recently.

Growth rate, size, and carcass composition cannot be considered in isolation of other important productive requirements and the increase in the incidence of dystocia in large breeds must be taken into account (Smith, Laster and Gregory, 1976).

Klosterman (1972) reported that cattle of various types and sizes fed to a similar finish, or grade, did not differ in feed efficiency. Smith _et al_. (1977) found that biological type did not significantly affect feed conversion efficiency when faster-gaining types were fed to the same net energy for production end-point. Smith _et al_. (1976b) showed that Limousin and Simmental crossbred steers were less efficient users of metabolizable energy than Hereford, Jersey, South Devon and Charolais crossbred steers when metabolizable energy values were adjusted to the same degree of finish (5% fat in _m. longissimus_).

Dikeman (1973, cited by Lipsey, Dikeman and Schalles, 1978) concluded that faster-gaining cattle used feed more efficiently than slower-growing cattle because of a dilution of maintenance requirements. In agreement with this statement, Lipsey, Dikeman and Schalles (1978) found that 16 Maine-Anjou and 14 Gelbvieh crossbred steers (out of Angus and Hereford dams) grew more rapidly and converted feed more efficiently than 16 Hereford x Angus reciprocal crossbred steers fed to the same energy co-efficiency end point of 8.0 M.Cal. of net energy (production) per kg gain. However, they also showed that within each type faster-gaining cattle were more efficient than slower-graining cattle. This latter finding differed from other studies at research stations in the United States which had shown little difference in feed conversion within a breed or type. Maine-Anjou and Gelbvieh steers were significantly longer and taller than the British steers. It should be mentioned that Lipsey, Dikeman and Schalles, (1978) were aware that their method of calculation of end points may not have been accurate.

The muscle to bone ratio (reviewed by Berg and Butterfield, 1966, 1968; Broadbent, Ball and Dodsworth, 1976) is known to differ between and within breeds of cattle. This ratio cannot be considered independently of level of fatness. For example, Truscott, Lang and Tulloh (1976) presented evidence which showed that Angus have a higher muscle to bone ratio than Friesians although there was no significant difference in the weight of muscle when they were compared at the same side weight. Angus had 4.8 kg more fat and 3.0 kg less bone than Friesians at the same dissected side weight.

Data presented by Berg and Butterfield (1976) based on a research project sponsored by the Royal Smithfield Club (Anon., 1966) showed that Herefords had a higher muscle to bone ratio than Friesians. Muscle to bone ratio is known to increase with an increase in carcass weight.

A higher muscle to bone ratio is one of the few carcass "advantages" British beef breeds have over dairy breeds. However it appears that

European breeds have higher muscle to bone ratios than British beef breeds (Berg, Andersen and Liboriussen, 1978a). The growth patterns and factors affecting growth of muscle, fat and bone have been described by Berg and Butterfield (1968, 1976) and it is well known that variation in percentage composition of the carcass (muscle, fat and bone) between breeds and crosses is greatly influenced by carcass fatness (Callow, 1948, see also reviews by Barton, 1967; Mason, 1971; Preston and Willis, 1974; Berg and Butterfield, 1976).

Most studies have concentrated on total fat and differences between breeds for this variable will not be considered here. It should be mentioned, however that Callow (1948) showed that the carcass fat depots grow differentially with subcutaneous fat having a higher impetus than intramuscular fat.

Cattle producers are placing greater emphasis on size and weight than formerly largely because of the performance of European breeds.

Abraham, Carpenter, King and Butler (1968) reported that longer carcasses yielded greater weights of boneless retail cuts, but did not have a greater percentage of retail cuts. Berry, Smith and Carpenter (1973) selected 100 carcasses of unknown background in the range short (106 to 114 cm, n = 21), medium (114 to 122 cm, n = 51) and long (122 to 130 cm, n = 28). Carcass weight averaged 248, 272 and 294 kg in the three groups, respectively. Carcass length was not significantly related to percent boneless retail cuts. There were only small differences in the percentage of boneless loin and boneless round between length groups although they were in favour of shorter carcasses.

The authors concluded that selection for longer-bodied cattle would have little effect on the ultimate yield of beef carcasses.

2.2 Aspects of liveweight growth in cattle

Growth in cattle normally follows a sigmoid pattern of liveweight growth from birth to maturity (Taylor, 1968; Joandet and Cartwright, 1970; Brown, Brown and Butts 1972; Berg and Butterfield, 1976). There are however, surprisingly few studies where liveweight has been reported over this age span, and plots of actual liveweight *versus* age seldom show such a definitive curve. However, Joandet and Cartwright (1969) plotted liveweight *versus* age of a crossbred cow from birth to 14 years of age, and Calo, McDowell, Van Vleck and Miller (1973) presented the average growth curve of 504 Holstein-Friesian bulls from 6 months to 9 years of age.

Large deviations from the expected curve of liveweight growth are caused by environmental factors (nutrition, health, climate,etc.) which result in seasonal patterns of liveweight growth of cattle in a pastoral environment (MacDonald, 1958; Barton, 1966; Allden, 1970; Scott, Rattray and Smeaton, 1976).

It is possible to alter the rate (within biological limits), and direction (weight loss, maintenance, or gain) of liveweight growth by manipulation of feed quality and quantity in a pastoral situation (Leaver, 1976). However, the grazier does not have the same degree of nutritional control over long periods of cattle growth as is the case with feedlot cattle.

Compensatory growth (Tanner, 1963) has a major effect on an animal's growth curve and contributes to the variability of liveweight growth in grazing cattle. The phenomenon enables an animal to "catch-up" to the equivalent weight of non-restricted animals by growing rapidly after a period of feed restriction.

Several studies (reviewed by Allden, 1970; Everitt and Jury, 1977) have shown that provided growth restriction is not applied early in life and, more importantly is not too severe, then cattle can compensate their liveweight growth to reach similar liveweights of their non-restricted contemporaries. The time taken to reach comparable liveweights depends on the severity of weight restriction and level of re-alimentation. However, Everitt and Jury (1977) found with monozygous twin dairy-type steers that compensatory growth failed to eliminate differences in liveweight between groups, one of which was underfed from shortly after birth to 16 weeks of age followed by a period of re-alimentation to slaughter at either 13 or 35 months of age. Whether such stunting is truly permanent cannot be determined from their study, although it has important implications for slaughter cattle grown within these ages.

Several New Zealand studies have shown the persistent effect of different pre-weaning environments on post-weaning growth of various types of cattle in a common environment (Everitt, Evans and Franks, 1969; Everitt, 1972; Dalton, 1976; Everitt and Jury, 1977). These studies showed that the ranking of initial and final weight of cattle grown in a common environment may be highly correlated as a result of differences in their pre-weaning environments. The "true" growth rate of such cattle can be obscured by compensatory growth because of pre-weaning feed restriction. However, the longer cattle are grazed in a common environment, the lower the effect of different pre-weaning environments on growth as judged by the correlation coefficients or regressions between initial weight and subsequent weights in these experiments. Most of the investigations cited above concluded before the cattle reached 20 months of age.

Even if a constant environment could be maintained for grazing cattle, their liveweights would be expected to vary about a common line of weight *versus* age because of short-term changes in liveweight (Clark and Campbell, 1969; Geay, 1976; Hughes, 1976), mostly due to daily changes in their gut content. Clark and Campbell (1969) and Hughes (1976) have suggested physical and statistical methods of reducing this type of liveweight variation.

The liveweight growth of a steer is under genetic as well as environmental control (for example, see Cundiff, Chambers, Stephens and Willham, 1964; Taylor, 1968; Joandet and Cartwright, 1969; Brown et al., 1972; Preston and Willis, 1974; Fitzhugh, 1976; Smith, Fitzhugh, Cundiff, Cartwright and Gregory, 1976a; Smith and Cundiff, 1976).

There is considerable genetic variation between and within different breeds of cattle for growth traits (liveweight at any age, average daily gain (ADG) and relative growth rate (RGR), which is generally expressed as the percentage change in weight relative to initial weight). These traits are of moderate to high heritability (See Preston and Willis, 1974; Smith and Cundiff, 1976) and are relatively easy to measure, especially when compared to the measurement of carcass traits.

There are large differences in mature size between breeds of beef cattle (Mason, 1971) and in the shapes of their growth curves. Joandet and Cartwright (1969) showed that there were differences in the shapes of growth curves and mature weights of 12 breed groups of cows (Hereford, and 11 crosses between Hereford and Brahman cattle). Brown, Brown and Butts (1972) found that there was considerable variation in the rate of maturing, and mature weight, between and within groups of Angus and Hereford cattle (i.e., cows, and a limited number of breeding bulls). Herefords appeared to be later maturing than Angus. The authors noted that cattle which made smaller changes in a measure of growth, than their contemporaries, were more likely to show changes in that trait for longer periods of time. There appeared to be a genetic antagonism between a high early growth rate and subsequent growth.

Calo, McDowell, Van Vleck and Miller (1973) studied the growth of 504 Holstein-Friesian bulls not directly selected for growth rate. They reported similar results to those of Brown et al. (1972) with the exception that there was no consistent relationship between growth rate at an early age and growth rate at subsequent ages. This difference may be due to the later relative maturity of Holstein-Friesian bulls than the Angus and Hereford cattle studied by Brown et al. (1972).

These studies, and other similar reports, can be explained in terms of differences in relative maturity. Early-maturing cattle make rapid gains relatively early in life (high RGR) compared to later-maturing types at similar ages (Smith and Cundiff, 1976).

Weight for age and average daily gain are genetically and phenotypically positively correlated with birthweight and mature size (Taylor, 1968; Seifert and Rudder, 1976). Thus selection for growth traits will alter the shapes of growth curves of cattle and their mature size.

Taylor (1968) and Cartwright (1970) consider that selection will have a greater influence on mature size than on the shape of the growth curve independent of mature size. However, Fitzhugh (1976) and Smith et al. (1976a) have suggested that selection based on relative growth rate, rather than weight for age, or average daily gain, would increase growth rate (hence change the shape of the growth curve) relatively more than it would alter mature weight.

In a study of relative growth rate in 477 crossbred and straightbred Angus, Hereford and Shorthorn steers, Smith and Cundiff (1976) concluded that selection for post-weaning (200 to 452 days), and post-natal (birth to 452 days), but not pre-natal relative growth rate, increased rate of growth and maturity at an early age. They reported large negative ($r = -0.61$) genetic correlations between RGR and birthweight, and moderate to large positive genetic correlations ($r = 0.74$) between RGR and post-weaning ADG, estimates of fatness, and efficiency of energy conversion.

The negative relationship between RGR and birthweight suggests a correlated reduction in mature weight would occur if selection for high RGR was successful. The concept of altering growth curves -

independently of mature weight - is of considerable importance in relation to long-term selection for growth traits, however, the limited amount of information on this subject means that it is unresolved at present.

2.3 Type and compositional differences

Stonaker, Hazaleus and Wheeler (1952) reported that "normal" Herefords from herds in which parents had been selected for size, grew faster than smaller-framed (compressed) Herefords. Similarly Wiley, Butler, Riggs, Jones and Lyerly (1951) found that larger-framed Hereford steers grew more rapidly than smaller-framed steers in a feedlot. Crickenberger and Black (1976) reviewed literature where different frame sizes of cattle had been evaluated under feedlot conditions and concluded that larger-framed cattle within a breed grew more rapidly than small-framed cattle. They found that selected Herefords grew faster than unselected Herefords (1.21 *verses* 0.91 kg/day), had heavier final weights (518.3 *versus* 438.9 kg) and had a similar feed conversion (3.61 *versus* 3.60 kg feed/kg gain).

Data from Brungardt (1972) cited by Crickenberger and Black (1976), are presented in Table 2.2. Cattle varying in size and growth were fed to reach Choice grade.

Table 2.2 Final weight, average daily gain (ADG), feed conversion ratio and percentage chemical fat in different frame sizes of Hereford (H) and Angus (A) cattle (Brungardt, 1972 cited by Crickenberger and Black, 1976)

Frame size 1	Breed	Final weight (kg)	ADG (kg)	Feed/Gain (kg)	Chemical fat %
1	H	403.1	1.20	2.62	-
2	H	433.9	1.28	2.57	-
3	H	478.4	1.35	2.79	-
4	H	502.0	1.37	2.77	-
5	H	532.8	1.46	2.90	-
1	A	397.7	1.21	2.76	30.1
2	A	446.2	1.29	2.84	32.4
3	A	464.3	1.31	2.90	33.9

1 Higher numbers denote larger frame size.

The results presented in Table 2.2 show that larger steers gained faster and weighed more than small steers and required more feed in growing to a similar degree of finish.

In another study, (Chrickenberger and Black, 1976) small and average-size Angus steers were selected from the same herd as calves and fed silage or grain rations. The average size Angus steers gained faster (1.11 *versus* 1.03 kg/day), were heavier (394.5 *versus* 353.7 kg empty body weight), required more feed to grow to a similar carcass compositional end-point (3.22 *versus* 3.00 feed/kg gain), and were leaner (27.53 *versus* 29.55% fat) than small size Angus steers. These workers concluded that there were no obvious economic advantages for any particular frame size of cattle under feedlot conditions because the increased liveweight and carcass weight gains of large-framed cattle did not pay for their higher non-feed costs which were levied in proportion to animal size.

Brungardt (1969) presented preliminary results from a study designed to evaluate the growth, feed conversion, carcass composition and other factors of economic importance in different types of Hereford steers. Five types of steers were evaluated ranging from blocky and squat (number 1) to rangy and leggy (number 5), in outline, and in overall appearance. Brungardt noted that it was difficult to find steers of numbers 1 and 5 types, while there was an abundance of number 3 type cattle in Hereford herds. Ten steers in each body type were selected from a total of 12 production-tested herds. The average age of the type groups varied by only 13 days. Fifty head were fed individually for 155 days on a high concentrate diet, then

8 out of the 10 steers in each group were slaughtered for carcass evaluation.

Some of the preliminary data from this study are presented in Table 2.3. These data show that as body type changed from blocky through to rangy there was an increase in growth rate during the intensive feeding period, and in overall growth (weight for age). Rangy steers were heavier on test, but also gained more during the test period. They were more profitable than blocky steers in terms of carcass value. All types graded Choice. Of great interest is the fact that if the final liveweights are plotted they appear to bear a linear and positive relationship to type, that is, there is no evidence of a decline in weight for age as type progresses from 1 to 5.

The growth and carcass data of rangy steers reported by Brungardt (1969) are consistent with those of later-maturing animals which grow faster and are therefore leaner at a similar carcass weight compared to earlier-maturing cattle. Luitingh (1962) found that the percentage of leg declined as carcasses increased in weight and fatness. This may explain the lower percentage of leg in rangy types shown in Table 2.3.

Clearly the large difference in final weight between types in Brungardt's study confounds direct comparison of carcass composition between the types.

Table 2.3 Performance data from five body types of Hereford steers (From Brungardt, 1969)

	Growth data (10 steers per body type)				
	Body Type				
	1	2	3	4	5
Weight off test (kg)	408.1	437.6	480.2	497.0	520.1
ADG on test (kg)	1.17	1.29	1.34	1.43	1.49
Weight for age (kg)	0.89	0.96	0.99	1.07	1.09
Feed/gain (kg)	3.12	2.99	3.17	3.12	3.17

	Carcass data (8 steers per body type)				
	Body Type				
	1	2	3	4	5
Carcass weight (kg)	248.0	263.9	288.8	307.0	319.7
Loineye area (cm^2)	76.5	77.4	77.8	76.6	76.5
Untrimmed round (%)	23.1	23.0	22.6	22.3	21.6
Fat cover (mm)	13.2	11.7	14.7	12.9	13.2
Cutability (%)	50.0	50.2	49.1	49.1	48.7
Preferred cuts (kg)	124.2	132.4	141.9	150.5	155.5

1 = Blocky and squat

5 = Rangy and leggy

2.4 New Zealand studies comparing the growth rate and carcass characteristics of Angus, Hereford and Beef Shorthorn steers

The growth rate and carcass characteristics of Angus, Hereford and Beef Shorthorn steers was compared in a series of experiments at Massey University (Barton, 1966; 1968; 1971a; and 1972). Included in these and other experiments in the series (Barton, 1973; Barton and Armstrong, 1974; Barton, 1975a) were Jersey, Milking Shorthorn, Ayrshire, Friesian, Galloway and Red Poll breeds and two crosses (Friesian-Jersey and Charolais-Jersey).

Some of the results for Angus (which was represented in every trial), Hereford and Beef Shorthorn steers are summarized in Table 2.4, in order of increasing carcass weight within a breed. Barton (1966) has discussed a number of problems inherent in this type of experiment.

The growth rate and carcass characteristics of Angus (A) and Hereford (H) steers was evaluated in five trials (Barton, 1966; 1968; and 1972). The results given in Table 2.4 show that Angus steers grew slower than Herefords in three trials, but the difference between the breeds ranged from +0.04 to -0.07 kg/day (A-H). Angus steers had lighter carcass weights than Herefords in four trials reflecting the difference in initial liveweight as well as slower growth rate. Carcass weight differences between the breeds ranged from +18 to -25 kg (A-H). Angus steers had lower dressing-out percentages (0.0 to 2.4%) in four trials, but they yielded a greater percentage of lean meat than Herefords in four trials (the overall range was from +2.8 to -1.4%, A-H). The difference in excess fat trim ranged from +2.3 to -3.0% (A-H) and that for bone from +1.4 to -1.4% over all trials (A-H). Angus steers had more kidney and channel

Table 2.4 Growth and carcass characteristics of Angus, Hereford and Beef Shorthorn steers

Trait												
Trial number	No. of steers slaughtered	Approximate starting and finishing age (months)	Days on trial	ADG (kg/day)	Carcass weight (kg)	Dressing-out %	Lean %	Excess fat % (incl. kidney and channel fat)	Trimmed bone %	Kidney and channel fat % (right side only)	Fat depth 12th rib (mm)	Ribeye area (cm^2)
						Angus steers						
IV	10	8-20	381	0.45	186	50.6	62.4	13.8	23.8	2.0	8.3	55.5
III	13	8-20	229	0.68	221	53.2	62.9	17.0	20.2	3.8	13.5	67.1
I	10	12-20	207	0.80	232	52.0	64.0	14.2	21.9	3.2	14.5	76.8
V	15	8-30	685	0.36	249	53.3	63.2	15.0	21.8	2.1	8.5	66.4
VIII	15	12-30	536	0.49	261	52.3	64.9	13.8	21.3	6.9	11.2	66.8
IX	13	8-30	694	0.45	271	52.9	63.5	14.3	22.2	4.6	10.5	67.7
VII	13	8-30	665	0.44	282	51.4	62.4	15.5	22.0	6.6	11.3	75.4
II	11	8-30	645	0.49	293	53.5	62.6	17.9	19.5	4.4	12.5	71.6
VI	15	12-30	530	0.51	303	53.9	60.7	18.3	20.9	8.1	12.5	68.3
						Hereford steers						
IV	10	8-20	381	0.51	212	51.2	61.1	13.7	25.2	2.3	7.6	52.9
III	13	8-20	229	0.75	238	53.2	64.3	14.7	21.1	2.8	12.2	62.6
I	10	12-20	207	0.75	257	54.4	62.2	17.2	20.4	4.2	19.6	76.1
VI	15	12-30	530	0.53	285	54.4	59.2	18.8	22.0	5.8	11.6	64.9
II	11	12-30	536	0.45	318	55.5	62.2	19.3	18.5	3.5	16.2	72.2
						Beef Shorthorn steers						
V	14	8-30	685	0.42	277	54.1	58.1	20.0	21.9	2.6	10.6	60.0
VI	14	12-30	530	0.42	285	54.4	56.4	22.3	21.4	8.6	13.6	59.3

Notes:

(1) Field data were not collected on all carcasses in some trials.

(2) Because of changes in dressing procedures carcass weight data are not strictly comparable.

(3) The data have been metricated.

(4) Sources: Trials I to III (Barton 1966); Trial IV (Barton 1968); Trial V (Barton 1971a); Trial VI (Barton 1972); Trial VII (Barton 1973); Trial VIII (Barton and Armstrong 1974); Trial IX (Barton 1975a).

fat than Herefords in three trials, the overall range was +2.3 to -1.0 kg (A-H). However Hereford steers tended to have a greater depth of fat over the ribeye of the 12th rib than Angus steers. The overall range was from +1.3 to -5.1 mm (A-H).

Barton reported that Angus steers had larger ribeye areas than Herefords in each of the five trials. This superiority ranged from 0.6 to 4.5 cm^2.

It is known that an increase in carcass weight is generally associated with an increase in dressing-out % and carcass fatness, and a decrease in the percentage of lean meat and bone (Preston and Willis, 1974; Berg and Butterfield, 1976). Therefore some of the differences between Angus and Hereford steers reported by Barton in his series of trials may reflect carcass weight differences.

Barton's results (Table 2.4) showed that most of the differences in carcass composition between Angus and Hereford steers were small and generally less than 3 percentage units. More importantly no consistent superiority was demonstrated between the two breeds with the exception of dressing-out % in favour of Herefords, and ribeye area in favour of Angus steers. Of possible academic interest was the result that Angus steers tended to have slightly greater weights of kidney and channel fat, while Herefords had slightly greater depths of subcutaneous fat. This might suggest a small difference in fat distribution between the two breeds.

Angus and Beef Shorthorn steers were compared in two trials (Barton, 1971a; 1972). Angus grew slower than Beef Shorthorns in the first trial and faster in the second trial (by 0.06 kg/day, and

0.09 kg/day, respectively). Despite the lack of consistent superiority in growth rate and carcass weight Barton (1971a; 1972) found that Angus steers had slightly lower dressing-out percentages (by 0.5 and 0.8%), a greater percentage of trimmed boneless lean meat (4.3 and 5.1%) reflecting a lower percentage of excess fat trimmed from the carcass (4.0 and 5.0%), and slightly less trimmed bone (0.1 and 0.5%). Table 2.4 shows that Angus steers had less kidney and channel fat (by 0.5 kg in both trials), a smaller depth of fat over the ribeye of the 12th rib (1.1 and 2.1 mm) and larger ribeye areas (4.4 and 9.0 cm^2) than Beef Shorthorns.

A difference of 4 to 5% in the yield of lean meat has commercial significance, as does the superior eye muscle area of Angus steers.

Beef Shorthorns tended to rank lower than Herefords for most carcass traits in one trial when the three breeds were compared (Barton, 1972). In view of the variability shown in five comparisons between Angus and Hereford steers it would be unwise to make generalizations based on only two comparisons between Angus and Beef Shorthorn steers. It is likely that if the breeds were compared at equal carcass weights the size of the difference in carcass composition would change. Barton (1975a) pointed out that until the information was analysed in more detail "Further interpretation of these data would be unwise".

Table 2.4 shows that, with a few exceptions, average differences in growth and carcass characteristics between Angus, Hereford and Beef Shorthorn steers were small. Reference to the original data (R.A. Barton, pers. comm.) shows that there was considerable variation in growth and carcass characteristics between animals within each of these breeds.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Source of data, selection of the steers

Trial X: Fifteen rangy and 15 short-type Angus weaner steers were selected by C.T. Wilton (Council member of the New Zealand Angus Association) from one farm in the Wairarapa.

Fifteen Beef Shorthorn weaners were bought from L.E. (now Sir Lewis) Harris of "Brooklands" Napier. These cattle were selected as conforming to the rangy-type and had been bred for large-frame size. The short-type Beef Shorthorn weaners were bred in the Martinborough district along more traditional "dumpy" lines. They were bought from a finisher.

Trial XI: The Angus weaners used in this trial were selected by K.B. Clayton (Council member of the New Zealand Angus Association), and P.H. Whitehead (Massey University) from two properties. Fifteen rangy steers were chosen from one farm near Akitio, where it was known that the breeding policy was for larger-framed cattle. The 15 short steers were purchased from another property in the same district.

R.A. Barton (Massey University) selected 15 rangy-type Hereford weaner steers and 15 short-type Hereford steers from one farm in the Kimbolton district. They were chosen from a line of about 60 weaners which had originated from a property in the Wairoa district.

3.2 Husbandry of the steers

The weaner steers were transported to the Massey University Terrace farm by truck. A few days after their arrival they were drenched, an identification number was tattooed on the inside of the right ear, and a plastic eartag was inserted in the same ear. There was a short settling-in period before each trial began. The steers were grazed together as one mob except when for pasture management purposes it was desirable to split them into smaller mobs for a period. Such mobs included both types and breeds. They were grazed entirely at pasture during their first year of life, but were supplemented with hay during periods of pasture shortage in the winter (about 2 kg/head/day). General management in each trial was aimed at near ad lib. feeding in the first year of each trial to achieve high growth rates.

In both trials the steers were confined in an open wintering-yard for a period in their second winter. While in the wintering-yard they were fed good-quality pasture hay at about 10 kg per head per day which was expected to maintain their liveweight at the time they were confined in the yard. The steers were moved from the confinement yard to "Ripley Rise" where they were grazed until slaughter.

General husbandry of the steers followed normal farm practices. They were drenched if there were indications that this could be beneficial. The cattle were weighed regularly usually directly off pasture, but while they were at "Ripley Rise" they were walked about 2 kilometers to the weighing scales. The same set of scales was used throughout the experiment, and weights were recorded to the nearest 0.5 kg.

Trial X began on 2 July, 1974, when all weaners were weighed. Weighing was repeated at intervals ranging from 24 to 91 days, until the final weighing on 18 March, 1976. The duration of the trial was 625 days.

Trial XI commenced on 21 July, 1975. The cattle were weighed at intervals of from 19 to 110 days until the completion of the trial on 14 April, 1977, that is, a period of 633 days.

The dates of weighing and interval between weighing dates for both trials are given in some of the figures and tables in Chapter Four.

3.3 Deaths during the grazing period

Trial X: The performance records of two steers were discarded from the rangy Angus group. One steer died of bloat, and the other had not been completely castrated. Thus 13 steers in this group remained throughout the trial.

One of the short-type Angus steers died, and one of the rangy-type Beef Shorthorn steers broke its leg, thus reducing the number of steers in each of these two groups to 14. There were no losses in the short-type Beef Shorthorn steers.

Trial XI: There were no losses of any of the steers in this trial.

3.4 Slaughter procedure

To ensure that breed group and type of steer were not confounded with day of slaughter, similar numbers of steers in each breed-type subgroup were represented on each slaughter day in both trials. The steers were allocated to a slaughter mob at random within the constraints mentioned above.

Set out in Table 3.1 is the number of steers in each slaughter mob, and the slaughter schedule for Trials X and XI, respectively.

In Trial XI a fasting treatment was imposed. Approximately half of the steers in each slaughter mob were allocated to either a control, or a fasted treatment. The fasted steers in each of the three slaughter mobs were weighed off pasture to obtain their pre-fasted liveweight. They were then held in open yards for four days without feed, but with access to water, before they were trucked to the abattoir.

On the day they were transported to the abattoir they were weighed to obtain their fasted liveweight. Hence by the time they were slaughtered (after the obligatory holding period at the abattoir from noon to slaughter the next day) the fasted steers had been held for 5 days without feed, but with access to water.

The steers in each of the three control groups were weighed off pasture whenever their fasted contemporaries were weighed. The experimental design for the fasting and non-fasting groups is presented in Table 3.2.

In the 1976/77 season the New Zealand Ministry of Agriculture and Fisheries regulations required that the cattle should arrive at the abattoir yards by midday on the day before slaughter. In both trials the steers left "Ripley Rise" by 10.00 am on the day prior to slaughter. They were trucked about 25 kilometres to the Feilding Abattoir and held there overnight in concrete yards.

Table 3.1 Slaughter schedule for the steers in Trials X and XI

Trial X, March 1976

Slaughter mob		1	2	3	4	5
Number of steers		9	12	11	12	12
Monday	22 March 1976	slaughter				
Tuesday	23	linear measurements	slaughter			
Wednesday	24	bone-out	linear measurements	slaughter		
Thursday	25		bone-out	linear measurements		
Friday	26			bone-out		
Monday	29				slaughter	
Tuesday	30				linear measurements	slaughter
Wednesday	31				bone-out	linear measurements
Thursday	1 April 1976					bone-out

Table 3.1 continued

Trial XI, April 1977

Slaughter mob		1	2	3
Number of steers		20	20	20
Tuesday	19 April 1977	slaughter linear measurements		
Wednesday	20	bone-out	slaughter linear measurements	
Thursday	21		bone-out	slaughter linear measurements
Friday	22			bone-out

Table 3.2 Design of the fasting treatment in Trial XI

Slaughter mob	1	2	3
Control (number)	10	11	11
Fasted (number)	10	9	9

Thursday	14 April 1977	weighed/fasted		
Friday	15	fasted	weighed/fasted	
Saturday	16	fasted	fasted	weighed/fasted
Sunday	17	fasted	fasted	fasted
Monday	18	weighed/trucked	fasted	fasted
Tuesday	19	slaughtered	weighed/trucked	fasted
Wednesday	20		slaughtered	weighed/trucked
Thursday	21			slaughtered

In the morning of slaughter the steers were spray washed and moved to the stunning race. The slaughter sequence was determined by the way the steers orientated themselves to go up the race under the urging of the stockman.

Slaughter began at about 7.00 am. Each steer was stunned using a captive bolt pistol, shackled to the half hoist position, washed around the tail area, hoisted to the upright position, and bled. Standard commercial procedures were followed in the dressing of each carcass.

3.5 Measurement and recording of carcass information

Data were recorded from carcasses on the killing chain, and in the chillers, and later in the boning-out room of Evans Export Ltd, Feilding. In 1976 when information from Trial X was being collected a maximum of only 12 steers was slaughtered on any one day so that there would not be any interruption to the normal flow of carcasses. However, with the co-operation of Evans Export Ltd it was possible to process 20 steers on each slaughter day in Trial XI.

Data collected from the killing chain

The ear tag, and works tag number (allocated to the carcass in killing order), for each steer was recorded after the beast had been stunned, bled, and hoisted to the rail.

The head was then removed at the atlanto-occipital articulation and the number, and the number of permanent incisor teeth were recorded.

The forelegs were removed at the metacarpus-radius articulation, and the hindlegs at the metatarsus-tibia-tarsus articulation. The carcass was then skinned, eviscerated, and sawn into halves. The kidney and channel (pelvic) fat was removed from each side according to normal practice, and the fat from each side was weighed to the nearest 0.01 kg. The carcass grade, and hot side weight (both sides per carcass) were recorded before each side was railed to the chiller (The carcass sides were weighed to the nearest 1 kg).

Data collected in the chillers

Various carcass measurements were taken from the right side using a flexible steel tape or plastic-coated measuring tape. Figure 3.1 indicates where these measurements were made on the carcass.

The length of the radius-ulna was determined by measuring the distance from the edge of the joint surface to the mid-point of the olecranon process.

In Trial XI an additional measurement was taken, this being the circumference of the muscles and other tissues which surround the radius ulna. This was estimated at a point mid-way along the length of the radius ulna and at right angles to its central axis.

The length of the carcass was measured from the anterior edge of the symphysis pubis to the anterior edge of the first rib parallel to the backbone.

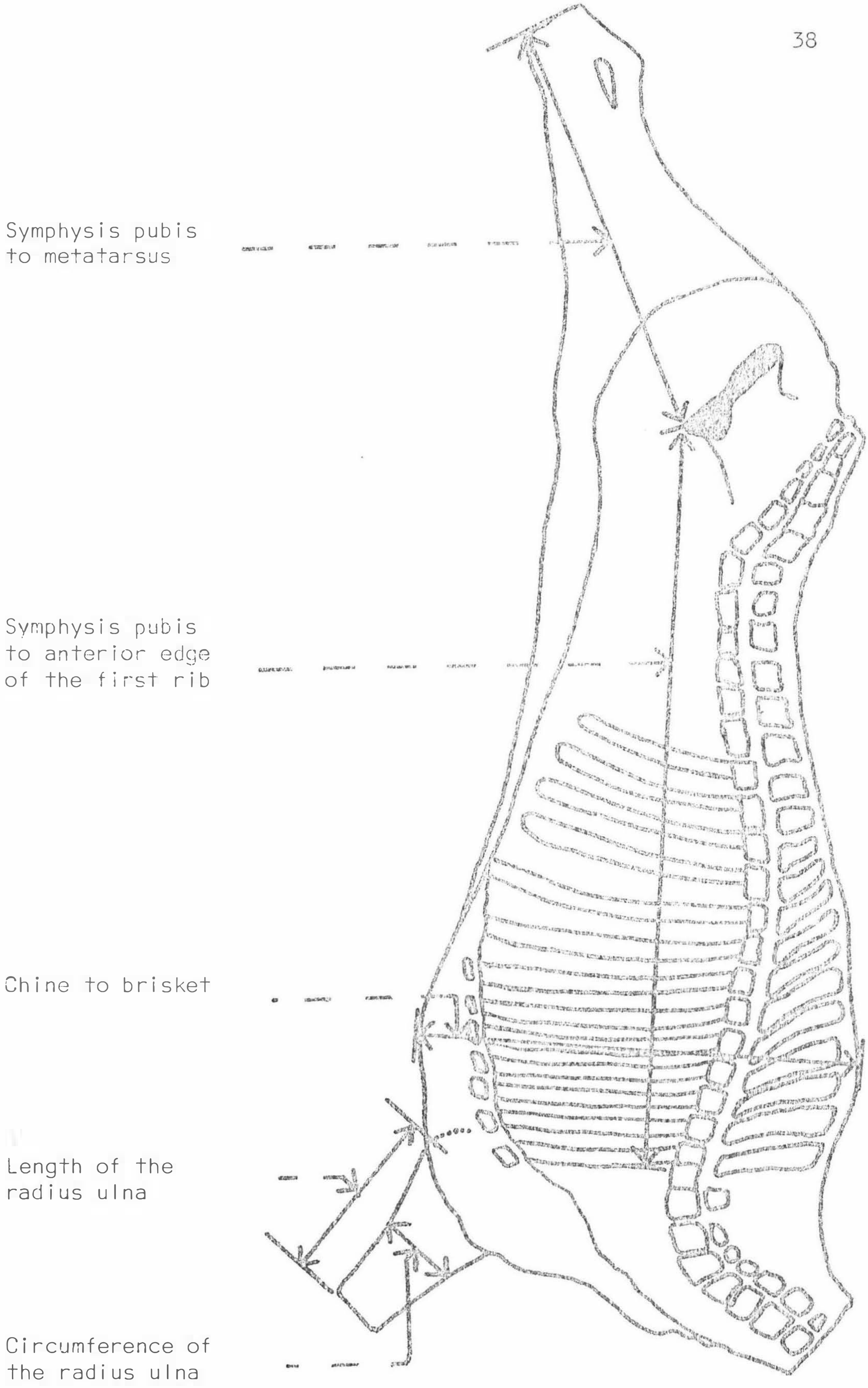

Fig. 3.1 Measurements taken on the right side of each carcass.

The length of the hind-limb was recorded as the distance from the anterior edge of the symphysis pubis to the anterior edge of the cut surface of the metatarsus-tibia-tarsus joint.

The depth of the carcass (from chine to brisket) was measured directly opposite, and almost parallel, to the 5th rib. This measurement included the depth of fat overlying the thoracic vertebrae and that underlying the sternum.

Fat colour was subjectively scored on the hot carcass. A sample of about 1 kg of _m. longissimus doris_ was removed from the left side of the carcass for meat quality determinations.

The carcasses remained in the chillers of the Feilding Abattoir for about 24 hours at an air temperature of approximately 5°C. They were then quartered by sawing through the vertebrae and by cutting with a knife between the 12th and 13th ribs with the blade held hard against the anterior edge of the 13th rib.

A tracing was made on acetate paper of the outline of the ribeye at the 12th rib.

The depth of fat over the 12th ribeye was measured at a point of the eye muscle two-thirds the distance from the chine bone using a steel rule. Each chilled side was subjectively scored for fat colour before quarters were severed from the side. The quarters were then moved to chillers owned by Evans Export Ltd, adjacent to the abattoir where they were boned-out (In Trial X they were held for 24 hours before boning-out took place).

Data collected in the boning room of Evans Export Ltd

The quarters were weighed to the nearest 0.1 kg. Any quarter requiring preliminary trim-out to remove contaminating material was so treated and the trimmings were weighed as a total for all quarters processed in any one day. (This preliminary fat trim was not done in Trial XI.)

The fore- and hind-quarter of the right side were boned-out separately, but on the same table, by an experienced boner. One boner, and two trimmers worked at each of three tables. Excess fat was trimmed from each cut to a specified level. The extent of trim was determined visually by the knife hands. The bones were weighed and the total lean trimmings from them were recorded and added as a mean to the total lean meat weight of each right side. Excess fat trim was weighed separately for each quarter. The weights of fat, and bone were recorded to the nearest 0.1 kg. The trimmed, boneless, lean meat yield was calculated for each quarter as the difference between the quarter weight and the sum of the weight of the bones and excess fat for that quarter.

3.6 Measurement of the area of the ribeye

An "Allbrit" planimeter was used to measure the area of each tracing of a ribeye using the exterior-pole method. Three non-consecutive measurements were made on each ribeye tracing taken in Trial X. The correlation between the two measurements which were widest apart was $r = 0.999$ (number of observations = 56, $P < 0.001$). Because the measurements were so highly repeatable the average of the 3 estimates for each ribeye was used in any calculations involving ribeye area.

In Trial XI, two non-consecutive measurements were made from each tracing. They were also highly correlated $r = 0.999$ (number of observations = 60, $P < 0.001$) and the average of the two measurements was used in calculations involving ribeye area.

3.7 Method of analysis

Analysis of growth and carcass data

The fitting constants method of analysis was used for most of these data, except those for which non-parametric analyses were appropriate.

Fixed effects linear models were assumed in all analyses where constants were fitted.

These models were:

Two-way nested classification

(3.1) $y_{ijk} = \mu + b_i + t_{ij} + e_{ijk}$

where:

y_{ijk} is the observation of the kth individual in the jth type group belonging to the ith breed group.

μ is a general mean

b_i is the effect due to the ith breed group, $i = 1, 2$.

t_{ij} is the effect due to the jth type group in the ith breed group, $j = 1, 2$.

e_{ijk} is the random error unique to y_{ijk}. Error effects were assumed to be independent and, for tests of significance, to be normally distributed.

Within breed one-way analysis of covariance

(3.2) $y_{ij} = \mu + t_i + \beta x_{ij} + e_{ij}$

where:

y_{ij} is the observation of the jth individual in the ith type group.

μ is a general mean.

t_i is the effect due to the ith type group, $i = 1, 2$.

β is the regression of the dependent variable (y) on the continuous independent variable (x).

x_{ij} is the independent variate for the corresponding y_{ij} observation.

e_{ij} is the random error unique to y_{ij}. Error effects were assumed to be independent and for tests of significance to be normally distributed.

The fitting constants procedure need not be repeated here as examples can be found in various texts (cf. Searle 1971).

An example analysis corresponding to model (3.1) is provided in Table 3.3. A solution to the normal equations was obtained after applying the constraints $\sum_{i=1}^{2} b_i = \sum_{\substack{i=1 \\ j=1}}^{2} t_{ij} = 0$.

Table 3.3 Example analysis of variance for the two-way nested classification (model 3.1).

Final liveweight of steers in Trial X

Source of variation	Degrees of freedom		Sum of squares	Mean square	F statistic
Mean	1	$R(\mu)$	15248665.79		
b_i after mean	1	$R\left(b_i \middle\| \mu\right)$	5480.56	5480.56	6.79 *
t_j within b_i after mean and b_i	2	$R\left(t_j : b_i \middle\| \mu, b_i\right)$	64884.46	32442.73	40.29 ***
Error	52		41919.18	806.13	
Total	56		15360949.99		

* = $P < 0.05$

*** = $P < 0.001$

Since the difference

$$\left(b_1 + \sum_{j=1}^{n} \frac{n_{1j} t_{1j}}{n_{1.}} \right) - \left(b_2 + \sum_{j=1}^{n} \frac{n_{2j} t_{2j}}{n_{2.}} \right)$$

is estimable, the hypothesis that the weighted breed effects are equal i.e.

$$H_o : b_1 + \sum_{j=1}^{2} \frac{n_{1j} t_{1j}}{n_{1.}} = b_2 + \sum_{j=1}^{2} \frac{n_{2j} t_{2j}}{n_{2.}}$$

is testable, and is tested by $R\left(b_i \middle| \mu\right)$.

The analysis in Table 3.1 indicates that there is a significant difference between the weighted breed effects ($P < 0.05$).

Since the difference $t_{ij} - t_{ij'}$ is estimable for all $j \neq j'$ within each breed i, the hypothesis equal type effects within a breed i.e. $H_o : t_{ij} = t_{ij'}$ is testable and is tested by $R\left(t_j : b_i \middle| \mu, b_i\right)$. The analysis shows type differences within a breed to be highly significant ($P < 0.001$).

An example analysis of covariance corresponding to model (3.2) is provided in Table 3.4. A solution to the normal equations was obtained after applying the constraint $\sum_{i=1}^{n} t_i = 0$.

Analyses of covariance were carried out within breeds to investigate the effect of adjusting certain traits for right side weight.

Table 3.4 Example analysis of covariance (model 3.2). Depth of fat over the ribeye of the 12th rib in Beef Shorthorn steers. The covariate was cold right side weight

Source of variation	Degrees of freedom		Sum of squares	Mean square	F statistic
Mean	1	$R(\mu)$	3313.79		
t_i after mean	1	$R\left(t_i \middle\vert \mu\right)$	15.67	15.67	2.14
Regression after t_i and mean	1	$R\left(\beta \middle\vert \mu, t_i\right)$	38.12	38.12	5.20 *
Error	26		190.40	7.32	
Total	29		3557.98		

* = $P < 0.05$

Since β is estimable, the hypothesis that the regression slope is zero i.e. $H_o : \beta = 0$ is testable and is tested by $R\left(\beta \mid \mu, t_i\right)$.

Since the difference $\left(t_1 + \beta x_i\right) - \left(t_2 + \beta x_i\right)$ is estimable, the hypothesis that the adjusted type means are equal i.e. $H_o : t_i + \beta x_i$ equal for all i is testable, and is tested by $R\left(t_i \mid \mu\right)$.

The analysis in Table 3.4 shows that the adjusted means do not differ significantly. The regression coefficient is significantly different from zero ($P < 0.05$).

Data for each steer were plotted against suitable axes (for example, time, weight or length). This gave an idea of their distribution and extraordinary observations could be noted and investigated.

Using the Statistical Package for the Social Sciences (S.P.S.S.) computing programme, the tests of skewness and kurtosis described by Snedecor and Cochran (1967) were applied to several variables. The small numbers of animals involved in the experiments meant that the statistical analysis yielded little information over and above that observed visually from the graphs.

Outlying observations were examined to see if they could have resulted in error, or if they were of biological importance.

Most texts warn against the rejection of data without good cause (Snedecor and Cochran, 1967; Sokal and Rohlf, 1969). In this experiment the cost of an experimental unit (one steer) was very high, therefore it was important to retain all meaningful data.

Liveweight and growth rate data were rejected from only those steers which died during the trial. Carcass data were not used from steers which were rejected for export because of disease.

Data were used for all variables recorded from the carcasses accepted for export, with the exception of some of the commercial cut-out data.

Two sets of the commercial cut-out data were rejected because they appeared atypical, taking into account normal carcass weight relationships, and the fact that a potential error was noted at the time the weights of trimmed bone and excess fat were recorded. The suspect observations from two steers were more than 3 standard deviation units outside the mean for weight of fat and bone, respectively. They could have been "estimated" (Snedecor and Cochran, 1967; Sokal and Rohlf, 1969) but this would place a low reliability on the yield of lean which was in turn estimated by the difference of trimmed bone and excess fat from the appropriate quarter weight. Because of this, all of the commercial yield data (weights and percentages of fat, bone and lean, in the right side of the carcass, and the ratio of lean to bone) for these two animals was omitted from further analysis.

Table 3.5 shows possible sources of variation in growth and carcass characteristics of steers in these trials. Only the effects of type within a breed group could be compared, the relative importance of other factors was unknown and confounded within a type group.

Table 3.5 Possible sources of variation in steers in Trials X and XI

Year of Slaughter	Breed	Type	Farm and herd	Selector
1976	Angus	rangy	A	1
		short	A	1
	Beef Shorthorn	rangy	B	2
		short	C	2
1977	Angus	rangy	D	3
		short	E	3
	Hereford	rangy	F	4
		short	F	4

Notes:

1. Similar letters or numbers indicate that steers were selected from the same farm and herd or by the same person or persons.
2. Age at purchase, and the sire and dam of each animal were unknown.

Analysis of the slaughter sequence of steers

As already stated the steers were allocated to each day of slaughter by restricted randomization to ensure that similar numbers of each breed and type were slaughtered daily. However they moved to slaughter under the urging of the stockman, not according to some randomly chosen sequence. An abattoir killing number was allocated to each carcass in slaughter sequence and this sequence is synonymous with slaughter rank. An analysis was carried out to investigate if there was any pattern in the order in which steers of each type and breed were slaughtered each day.

Non-parametric statistical methods appropriate to testing the distribution of rank numbers (Siegel, 1956) were used in the analysis of these data. The objective was to test the null hypothesis "that the various groups did not differ in their slaughter location".

The slaughter rank sums of the type, breed, and fasting treatment groups (in Trial XI) were tested using the following statistical criteria.

The Kruskal-Wallis test (Sokal and Rohlf, 1969) was applied to the data in both trials to see if the type groups differed in their slaughter "location", that is, if any one group had more members slaughtered ahead of those of another group within each day.

The Wilcoxon two-sample test (Sokal and Rohlf, 1969) was used to test if the breed groups (in both trials), and the fasted and non-fasted groups (in Trial XI) differed in their slaughter "location".

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results of the analysis of slaughter sequence

The results of the analysis of slaughter location for Trial X steers are given in Table 4.1.

The test statistic for the type, and breed groups on each day of slaughter are presented.

The results given in Table 4.1 show that there was no significant difference ($P < 0.05$) between the four types, or the two breed groups in their slaughter location on any of the five days of slaughter. Nor was there a consistent trend in the order of slaughter of these groups of steers. The Beef Shorthorn steers tended to come forward ahead of the Angus steers on day one (the difference almost reached significance), but this trend was not repeated on other days of slaughter and probably occurred by chance.

The pre-slaughter liveweight of each steer was plotted against its slaughter sequence number to determine if any relationship existed between these variables for each group of steers and over all steers on each day of slaughter. No relationship was apparent.

Table 4.1 Slaughter rank test statistic for type and breed groups on each day of slaughter in Trial X

Slaughter day	Type groups test statistic 1	Breed groups test statistic 2
1	4.90	19
2	1.87	18
3	2.37	19
4	2.79	26
5	3.35	21

1 Kruskal-Wallis test statistic critical value = 6.25 ($P < 0.10$).

2 Wilcoxon two-sample test statistic critical value : day 1 = 19; day 3 = 27; days 2, 4 and 5 = 31 ($P < 0.05$).

The results of Trial XI are given in Table 4.2 which show the test statistics for the type, breed and the fasted and non-fasted treatment groups.

There was no significant difference in slaughter "location" between the type groups, the breed groups, or the fasted treatment groups.

The pre-slaughter liveweight and carcass weight of each steer were plotted against its slaughter sequence number for each group. No association was apparent on a within group basis, however there appeared to be a slight relationship between the weights and slaughter sequence numbers over all steers within each day of slaughter.

Kendall's coefficient of rank correlation (Sokal and Rohlf, 1969) was calculated for all the steers slaughtered on each day, between pre-slaughter liveweight rank, and carcass weight rank *versus* slaughter sequence. The coefficients are presented in Table 4.3 and are low and non-significant ($P < 0.05$).

Carcass weight was included in the calculations as well as liveweight as it was known that the fasting treatment affected pre-slaughter liveweight more than it did carcass weight. The results in Table 4.3 show there was little change in the correlation if carcass weight or liveweight were used. These results indicate that there was no statistically important differences in slaughter location between the type, breed, and fasted treatment groups in Trial XI. Nor were there any important

Table 4.2 Slaughter rank test statistic for type, breed and fasted treatment groups on each day of slaughter in Trial XI

Slaughter day	Type groups test statistic 1	Breed groups test statistic 2	Fasted treatment groups test statistic 2
1	3.11	61	55
2	5.26	64	53
3	1.58	54	61

1 Kruskal-Wallis test statistic critical value = 6.25 ($P < 0.10$).

2 Wilcoxon two-sample test statistic critical value = 73 ($P < 0.10$).

correlations between pre-slaughter liveweight, carcass weight and slaughter sequence over all the steers with each day of slaughter despite the large weight range of steers slaughtered on the same day.

A greater number of steers were slaughtered each day in Trial XI than in Trial X, but the fasting treatment which was imposed on about half of these steers disrupted their grazing.

It would appear that in both trials the steers moved to slaughter in a random manner independent of their breed-type, and breed groups. Slaughter sequence did not seem to be related to pre-slaughter liveweight.

Daily group numbers were small and the steers had been randomly allocated to each day of slaughter, hence there would have been a disruption to any leadership order that had evolved during the grazing period. The effect of the stockman in guiding the steers up the stunning race could also have been an important factor in determining slaughter sequence, especially with small number of steers slaughtered each day.

The analysis of slaughter sequence was undertaken to determine if there were any important, or consistent, relationships between the various treatment groups and their order of slaughter. It could have important implications with respect to the data collected in these trials.

Table 4.3 Kendall's coefficient of rank correlation (τ) between slaughter sequence and pre-slaughter liveweight rank *versus* carcass weight rank 1

	Slaughter sequence *versus*:	
	pre-slaughter liveweight rank	carcass weight rank
Number of steers	20	20
Slaughter day		
1	0.18	0.18
2	0.13	0.07
3	0.28 †	0.29 †

1 The weights were ranked from highest to lowest.

† Not significant at $P < 0.05$, but significant at $P < 0.10$.

4.2 Results of the analysis of liveweight and growth rate

Trial X - Types within Angus steers

Rangy steers were about 5% heavier than short steers throughout the trial as can be seen in Table 4.4 and Fig. 4.1. The difference was not statistically significant until the seventh weighing, but was significant in five out of the last eight weighing dates. There was no significant difference in the ratio of the within type variances in liveweight on any weighing date. This suggests that visual selection was quite efficient in choosing two groups of steers with similar variability in liveweight.

Comparison of average daily gains for each type in Table 4.5 shows that there was no consistent advantage of one type over the other during the trial. Average daily gains differed significantly ($P < 0.05$) between the two types in period 6. During this period the short steers lost weight at a rate of 0.16 kg/day while the rangy steers maintained their liveweight. When the average daily gains given in Table 4.5 are compared with mean liveweights in Table 4.4 it can be seen that although the rangy steers gained 12.6 kg more liveweight than the short steers over the whole trial (about 0.02 kg/day for 625 days), most of the difference arose in period 6 when the short steers lost 8.6 kg liveweight over 54 days while rangy steers maintained their liveweight.

The ratio of within group variances for average daily gain was analysed for each weighing period in Table 4.5. Variances differed significantly on two occasions, rangy steers were more variable ($P < 0.05$) in period 11, but short steers were more

Preface to Table 4.4 and to all Tables and Figures which follow in Chapter Four unless otherwise specified

* = $P < 0.05$, ** = $P < 0.01$, *** $P < 0.001$.

SE = standard error of the difference.

ADG = average daily gain.

A = ratio of the within group variances was examined in all analyses because the test of significance assumes equal variances. The letter A indicates unequal variances. This was taken into account in the test of significance.

Difference between types best linear unbiased estimate = $t_{ij} - t_{ij'}$, $j \neq j'$ model (3.1).

Weighted difference between breeds best linear unbiased

$$\text{estimate} = \left(b_1 + \sum_{j=1}^{n} \frac{n_{1j} t_{1j}}{n_{1\cdot}}\right) - \left(b_2 + \sum_{j=1}^{n} \frac{n_{2j} t_{2j}}{n_{2\cdot}}\right)$$

model (3.1).

Difference between the adjusted means best linear unbiased estimate = $\left(t_1 + \beta x_i\right) - \left(t_2 + \beta x_i\right)$

model (3.2).

Table 4.4 Means, differences and standard errors between the two types of Angus steers for liveweight on each weighing date in Trial X

Weighing date	Angus Rangy n = 13 Mean (kg)	Angus Short n = 14 Mean (kg)	Weight Difference (Rangy-Short) (kg)	± SE (kg)
1974				
July 2	234.2	221.3	12.9	6.2
Aug 28	262.1	251.3	10.8	6.5
Oct 24	319.5	305.4	14.1	7.3
Dec 24	347.4	334.4	13.0	8.1
1975				
Jan 31	358.0	342.3	15.7	8.3
Apr 4	349.2	334.9	14.3	8.4
May 28	348.8	326.0	22.8 *	8.1
June 27	367.4	346.0	21.4 *	9.2
July 21	386.5	364.2	22.3 *	10.1
Sept 8	380.4	361.2	19.2	9.5
Oct 13	394.1	374.0	20.1 *	9.6
Nov 17	453.2	433.3	19.9	11.8
1976				
Feb 16	530.8	505.1	25.7 *	12.8
Mar 18	545.7	520.2	25.5	12.6

Table 4.5 Means, differences and standard errors between the two types of Angus Steers for average daily gain in Trial X

Weighing period	Interval between weighings (days)	Angus Rangy n = 13 Mean (kg/day)	Angus Short n = 14 Mean (kg/day)	Difference in ADG (Rangy-Short) (kg/day)	± SE (kg/day)
1	57	0.49	0.53	-0.04	0.04
2	57	1.00	0.95	0.05	0.05
3	61	0.46	0.47	-0.01	0.05
4	38	0.28	0.21	0.07	0.10
5	63	-0.14	-0.12	-0.02	0.07
6	54	0.00	-0.16	0.16 *	0.05
7	30	0.62	0.67	-0.05	0.09
8	24	0.80	0.76	0.04	0.12
9	49	-0.12	-0.06	-0.06	0.07
10	35	0.39	0.36	0.03	0.12
11	35	1.69	1.69	0.00 A	0.12
12	91	0.85	0.79	0.06 A	0.03
13	31	0.48	0.49	-0.01	0.09
Overall	625	0.50	0.48	0.02	0.01

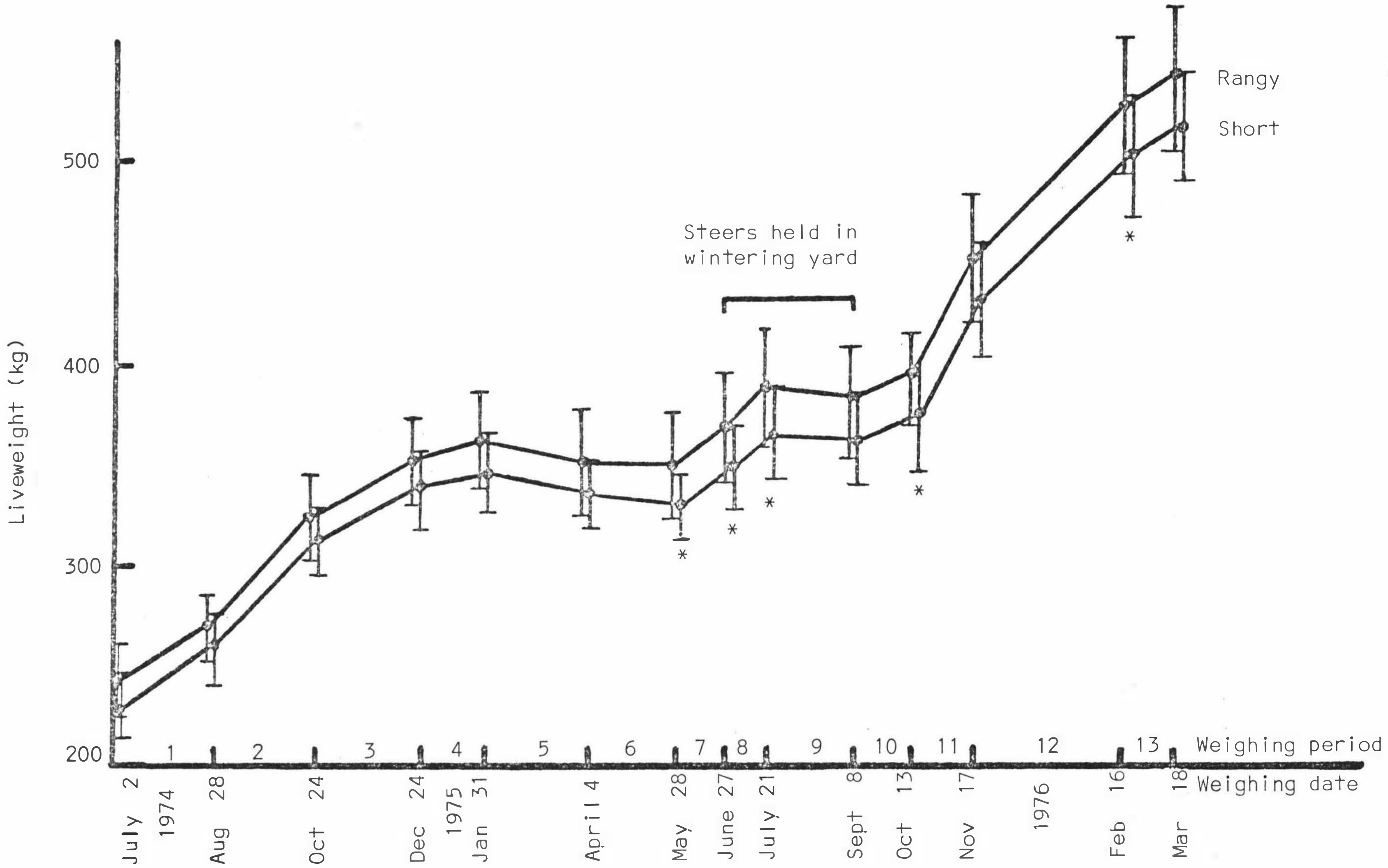

Fig. 4.1 Average liveweights and standard deviation bars for rangy- and short-type Angus Steers in Trial X *versus* weighing period and weighing date.

variable ($P < 0.01$) in period 12. These changes in variability are difficult to interpret in any meaningful manner and probably only reflect changes in gut fill which is a major component of short-term variation in liveweight (Hughes, 1976).

Phenotypic correlation coefficients were calculated between initial and final liveweight for each of the two types of steers in Trial X. The correlations give an indication of the repeatability of liveweight. Within-type correlations between initial and final liveweight were $r = 0.71$ ($n = 13$, $P < 0.01$) for rangy, and $r = 0.32$ ($n = 14$, n.s.) for short steers. The high repeatability of liveweight in the rangy group indicates that the selector was successful in choosing a group of steers which tended to rank in a similar order of liveweight at the beginning and end of the experiment. This was not the case in the short group of steers.

Brungardt (1972), cited by Crickenberger and Black (1976), reported a much larger difference in growth rate (0.10 kg/day) than that observed in this trial between extreme frame sizes of Angus steers fed a high concentrate ration for 155 days. Crickenberger and Black (1976) found that "average" steers grew 0.08 kg/day faster than "small" size Angus steers.

The results of Trial X show that the selection of two types of Angus steers from the same farm did not result in significant differences in initial liveweight, or in subsequent growth rate. The rangy steers were able to maintain their liveweight during a period of autumn feed shortage for some unexplained reason, while short steers lost weight.

Rangy steers were a more homogeneous group than short steers which probably reflects differences in the effectiveness of visual selection, rather than any intrinsic property of the cattle. It was noted at the time of selection that there was not a wide range of type in the line of Angus steers (R. A. Barton, pers. comm.).

The two groups of steers actually gained 13 kg and 15.2 kg liveweight (rangy and short, respectively) while being fed hay in a wintering yard for 73 days (no significant difference between types). This demonstrates the successful use of such a yard at a time when heavy cattle can pug pastures.

Trial X - Types within Beef Shorthorn steers

There was a very large difference in average liveweight and growth rate between the two types of Beef Shorthorn steers. The difference in liveweight was highly significant ($P < 0.001$) throughout the trial (Fig. 4.2 and Table 4.6). Rangy steers were approximately 27% heavier at the start than their short contemporaries and about 21% heavier at the end of the trial. Rangy steers were slightly more variable in liveweight than short steers until the last four weighings of the trial. The ratio of within type variances in liveweight was significant (rangy > short, $P < 0.05$) on 24 December 1974. Both groups of steers were gaining weight at similar rates at the time and significance was probably due to random variation in gut fill as well as the tendency for rangy steers to be more variable in their liveweights.

Table 4.7 shows that rangy steers grew 0.07 kg/day faster ($P < 0.001$) than short steers over the 625 days of the trial, that is, an increase of 41.6 kg liveweight. Rangy steers had higher values for average daily gain in eight of thirteen weighing periods. Differences were statistically significant for three periods when the growth rate of both types of steers was high. This occurred in the spring of 1974 and 1975 (periods 2 and 11, respectively), when steers were on an increasing plane of nutrition, and in the winter of 1975 after the steers had been transferred to a wintering yard.

Rangy steers however, did not maintain their overall superiority in growth rate throughout the trial, in fact the short type steers gained liveweight at a significantly greater rate than the rangy steers during period 4 (summer 1975). They also gained weight faster than the rangy steers for a short period in the summer of 1976 (period 13), but the difference was not statistically significant.

The ratio of within-type variances in average daily gain was not consistent in terms of one type being more variable than the other.

The correlation between initial and final liveweight was positive in each group of steers, but not significantly different from zero (rangy $r = 0.38$, $n = 14$ n.s.; short $r = 0.35$, $n = 15$ n.s.). These correlations are of a similar order of magnitude to those in the short group of Angus steers and indicate that the heaviest steers at the start of the trial were not necessarily the heaviest at the end of the trial.

Table 4.6 Means, differences and standard errors between the two types of Beef Shorthorn steers for liveweight on each weighing date in Trial X

Weighing date	Shorthorn Rangy n = 14 Mean (kg)	Shorthorn Short n = 15 Mean (kg)	Weight Difference (Rangy-Short) (kg)	± SE (kg)
1974				
July 2	231.0	181.3	49.7 ***	4.1
Aug 28	259.9	212.7	47.2 ***	5.7
Oct 24	324.2	265.0	59.2 ***	7.2
Dec 24	364.0	295.0	69.0 ***A	7.1
1975				
Jan 31	369.1	307.9	61.2 ***	6.1
April 4	357.4	294.7	62.7 ***	6.8
May 28	349.3	294.8	54.5 ***	7.0
June 27	374.7	317.5	57.2 ***	6.9
July 21	404.1	338.3	65.8 ***	7.4
Sept 8	400.0	328.5	71.5 ***	6.5
Oct 13	405.6	334.9	70.7 ***	7.7
Nov 17	465.3	381.7	83.6 ***	8.0
1976				
Feb 16	554.9	459.6	95.3 ***	8.9
Mar 18	560.0	468.6	91.4 ***	9.0

Table 4.7 Means, differences and standard errors between the two types of Beef Shorthorn steers for average daily gain in Trial X

Weighing period	Interval between weighings (days)	Shorthorn Rangy n = 14 Mean (kg/day)	Shorthorn Short n = 15 Mean (kg/day)	Difference in ADG (Rangy-Short) (kg/day)	± SE (kg/day)
1	57	0.50	0.55	-0.05	0.07
2	57	1.13	0.92	0.21 *	0.10
3	61	0.65	0.50	0.05	0.07
4	38	0.13	0.34	-0.21 *	0.07
5	63	-0.18	-0.21	0.03	0.06
6	54	-0.15	0.00	-0.15 A	0.08
7	30	0.85	0.76	0.09	0.10
8	24	1.23	0.87	0.36 **	0.12
9	49	-0.08	-0.20	0.12	0.05
10	35	0.16	0.18	-0.02	0.10
11	35	1.70	1.34	0.36 *	0.13
12	91	0.98	0.86	0.12	0.05
13	31	0.16	0.29	-0.13	0.08
Overall	625	0.53	0.46	0.07 ***	0.01

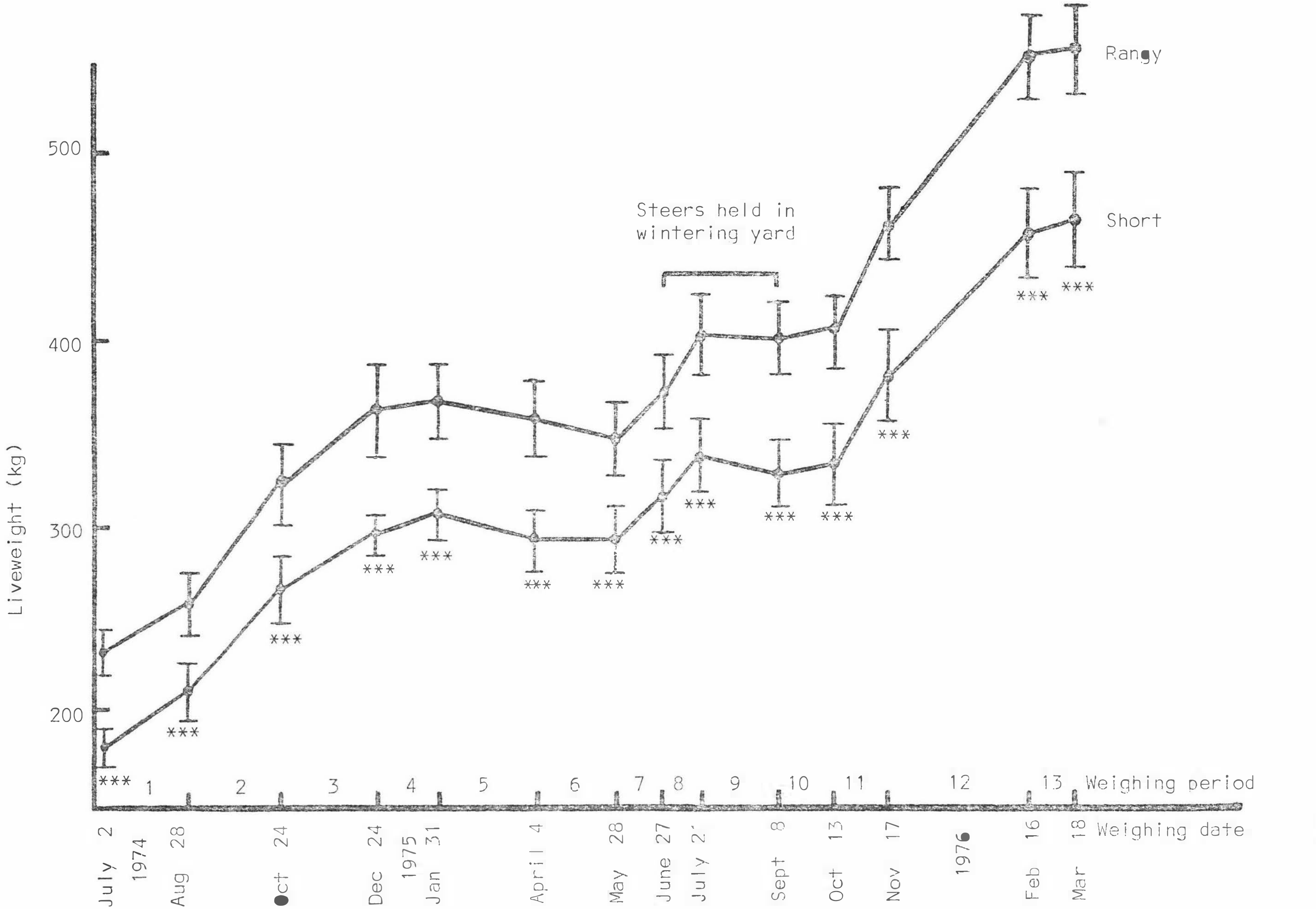

Fig. 4.2 Average liveweights and standard deviation bars for rangy- and short-type Beef Shorthorn steers in Trial X *versus* weighing period and weighing date.

Because the two types were each selected from a different herd and farm there were many sources of genetic and environmental variation which could explain the large difference in initial liveweight between them.

If the short group of steers had been poorly grown to weaning (nutritional stress) they would have shown some degree of compensatory growth when the two groups were run together in a common environment (Allden, 1970; Everitt and Jury, 1977). The average growth rates in Table 4.7 and Fig. 4.2 do not suggest that any compensatory growth occurred, at least on a type group basis.

As the age (birth date) of the steers was unknown it was possible that some of the difference in initial liveweight between the two types was due to a difference in age. Assuming a similar birthweight and growth rate to the commencement of the trial of 0.5 kg/day, the average birth date of the two groups would have had to differ by almost three months (100 days) to account for all of the difference in initial liveweight. It was known that there was not such a wide discrepancy in average calving date between the two herds and that it could not have differed by more than two or three weeks. The difference in growth rate between the types over the whole trial therefore does not suggest that initial weight differences were due to age alone.

The genetic effects of sire and dam were unknown, however, there was a known difference in breeding policy between the two sources of steers. The herd from which rangy steers were selected was renowned for breeding "large-framed" cattle, while the herd in which the short-type steers were bred was known to produce more traditional "blocky" cattle.

It can be argued, therefore, that the suprior growth performance of rangy *versus* short steers mainly reflects the effect of two biological types of cattle.

The experiment raises the important question of how much of the advantage is due to type per se compared to an undefined selection policy which, among other traits, affected growth rate to weaning. Obviously there is confounding between type and growth rate, but this is an important question in relation to present beef cattle performance recording schemes. Rangy Beef Shorthorn steers gained significantly more weight in the wintering yard than short-type Beef Shorthorn steers (14.3 kg, $P < 0.01$). Both types of Beef Shorthorns gained weight (rangy 25.3 kg, short 11.0 kg) in the yard despite being fed a "maintenance" ration of hay. It is possible some of the gain could be due to gut fill as a consequence of the change of diet from pasture to hay. Liveweight gain for both types of Angus and Beef Shorthorn steers in the wintering yard ranked: Beef Shorthorn rangy > Angus short > Angus rangy > Beef Shorthorn short. These differences were not tested statistically as type was nested within a breed.

Trial X - Comparison of Breed Groups

Angus steers were consistently heavier in mean liveweight than the Beef Shorthorn steers, the difference tended to be statistically significant ($P < 0.01$ to $P<0.05$) only in the first half of the trial (Fig. 4.3). Beef Shorthorn steers grew faster than Angus steers in seven of the first eight weighing periods, but the Angus steers tended to have higher growth rates in the latter part of the trial (Table 4.8). Hence although the breed groups had significantly different growth rates in various weighing periods, they tended to cancel each other out and this resulted in no difference over the 625 days of the trial.

Other studies at Massey University have not shown a consistent superiority in either growth rate or liveweight of Angus or Beef Shorthorn breeds over one another (Barton 1971, 1972). Growth rate in Barton's trials differed by 0.06 and 0.09 kg/day in favour of Beef Shorthorn and Angus steers respectively, which means the present results lie about mid-way between those of earlier experiments.

The similar growth performance of the two breeds highlights the variation that existed within them (cf. types within each breed). It is of interest that there appeared to be more variation in type in Beef Shorthorn than Angus steers. Whether this reflects true population differences or is a consequence of the method of selection cannot be determined in an experiment of this nature.

Growth patterns of the breed groups suggest Angus may have been slightly later maturing than Beef Shorthorns.

It must be stressed that the experiment was not undertaken to provide evidence on differences between the breeds but to evaluate differences between types within each breed.

Table 4.8 Weighted means, differences and standard errors between the two breed groups for average daily gain in Trial X

Weighing period	Interval between weighings (days)	Angus n = 27 Mean (kg/day)	Beef Shorthorn n = 29 Mean (kg/day)	Difference in ADG 1 (Angus Shorthorn) (kg/day)	± SE (kg/day)
1	57	0.50	0.52	-0.02 A	0.04
2	57	0.98	1.02	-0.04 A	0.06
3	61	0.46	0.57	-0.11 *A	0.04
4	38	0.24	0.24	0.00	0.06
5	63	-0.13	-0.20	0.07	0.04
6	54	-0.09	-0.08	-0.01	0.05
7	30	0.64	0.80	-0.16 *	0.07
8	24	0.78	1.04	-0.26 **	0.09
9	49	-0.09	-0.14	0.05	0.04
10	35	0.38	0.17	0.21 **	0.07
11	35	1.69	1.52	0.17 *	0.10
12	91	0.82	0.92	-0.10 * A	0.03
13	31	0.48	0.23	0.25 **	0.08
Overall	625	0.49	0.49	0.00	0.01

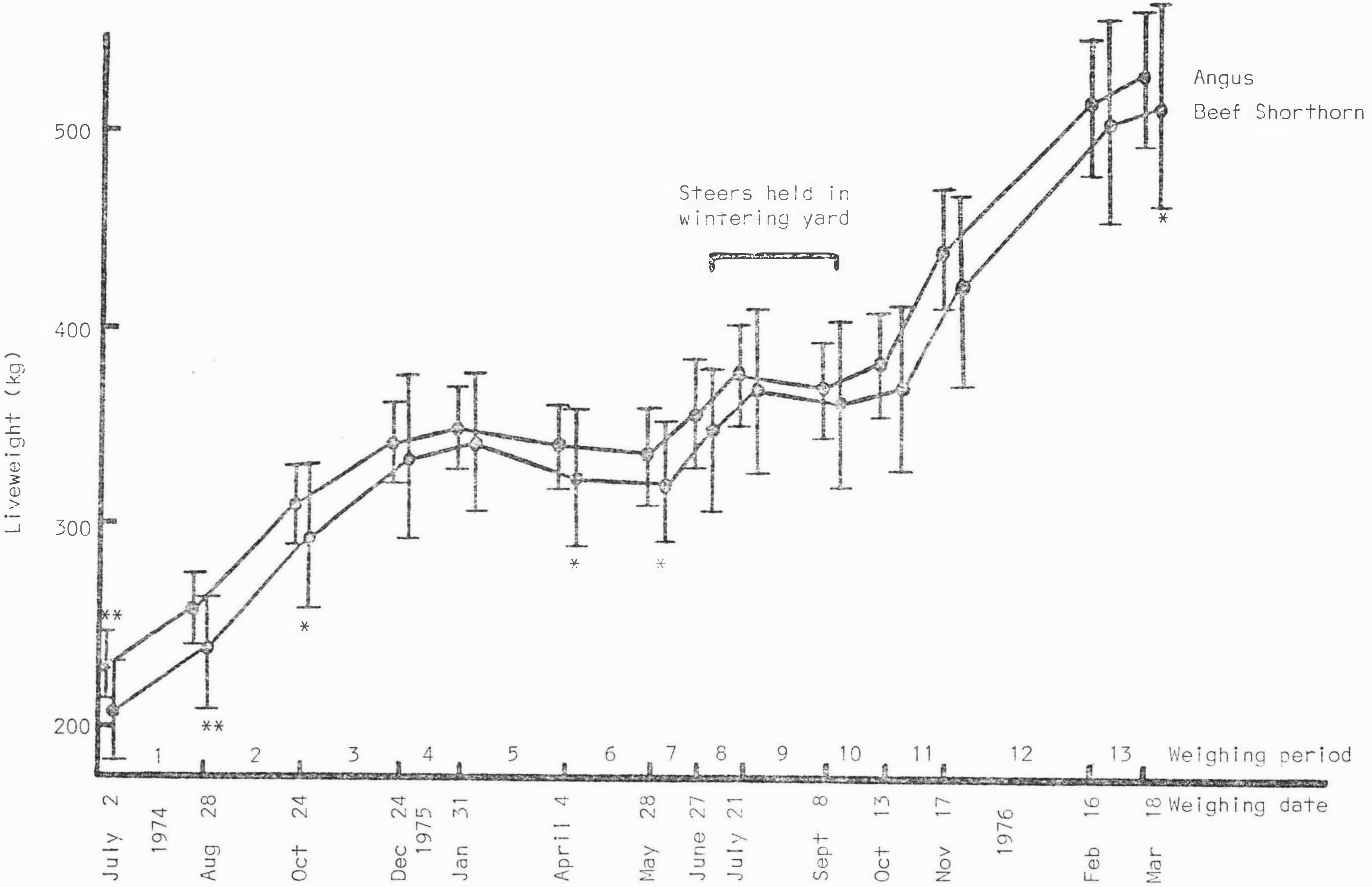

Fig. 4.3 Average liveweights and standard deviation bars for Angus and Beef Shorthorn steers in Trial X *versus* weighing period and weighing date.

In terms of growth rate over the whole trial the groups ranked: Beef Shorthorn rangy > Angus rangy > Angus short > Beef Shorthorn short. Differences between all the groups were not tested statistically as type was nested within a breed. The difference between each group (as ranked above) was about 0.02 kg/day.

Trial XI - Types within Angus steers

Table 4.9 shows there was a highly significant difference in initial liveweight between the two types of Angus steers ($P < 0.001$). Rangy steers were about 19% heavier than short steers, a much larger difference than that for Angus types in Trial X, but of a similar order of magnitude to the Beef Shorthorn types. The mean liveweights of the two types differed significantly throughout most of the trial ($P < 0.05$ to $P < 0.001$), but by the end of the trial rangy steers were only 4% heavier than short steers because the short steers had grown 0.03 kg/day (n.s.) faster over the whole trial.

The ratio of within type variance in liveweight was not statistically significant between the two groups on any weighing date, nor was there any consistent trend over the whole of the trial.

Table 4.10 shows that the short steers grew faster than the rangy steers in eight of the twelve growth periods. The difference was statistically significant ($P < 0.05$) only in period 7 that is, while the steers were confined in a wintering yard. Table 4.10 shows that the short Angus steers made their greatest gains in liveweight (over the rangy steers) in the first seven weighing periods which could suggest some degree of compensatory growth.

Table 4.9 Means, differences and standard errors between the two types of Angus steers for liveweight on each weighing date in Trial XI

Weighing date	Angus Rangy n = 15 Mean (kg)	Angus Short n = 15 Mean (kg)	Weight difference (Rangy-Short) (kg)	± SE (kg)
1975				
July 21	263.7	220.8	42.9 ***	6.1
Sept 24	275.2	231.7	43.5 ***	6.7
Oct 13	292.1	253.9	38.2 ***	7.4
Nov 17	325.5	292.1	33.4 ***	7.3
1976				
Feb 16	380.9	345.1	35.8 ***	7.4
Mar 18	394.5	364.1	30.4 ***	8.2
July 6	405.0	376.7	28.3 ***	7.0
Aug 24	414.1	396.8	17.3	8.9
Sept 23	404.4	385.3	19.1 *	7.7
Nov 10	451.1	434.4	16.7	8.6
Dec 21	501.4	474.7	26.7 *	10.4
1977				
Feb 16	533.9	508.9	25.0 *	9.3
April 14	540.8	519.6	21.2 *	8.9

Table 4.10 Means, differences and standard errors between the two types of Angus steers for average daily gain in Trial XI

Weighing period	Interval between weighings (days)	Angus Rangy n = 15 Mean (kg/day)	Angus Short n = 15 Mean (kg/day)	Difference in ADG (Rangy-Short) (kg/day)	± SE (kg/day)
1	65	0.18	0.17	0.01	0.06
2	19	0.89	1.17	-0.28	0.22
3	35	0.95	1.10	-0.15 A	0.08
4	91	0.61	0.58	0.03	0.03
5	31	0.45	0.63	-0.18 A	0.20
6	110	0.10	0.11	-0.01	0.05
7	49	0.17	0.39	-0.22 *	0.09
8	30	-0.35	-0.41	0.06	0.16
9	48	0.97	1.02	-0.05	0.05
10	41	1.23	0.98	0.25	0.12
11	57	0.57	0.60	-0.03	0.07
12	57	0.12	0.19	-0.07	0.05
Overall	633	0.44	0.47	-0.03	0.01

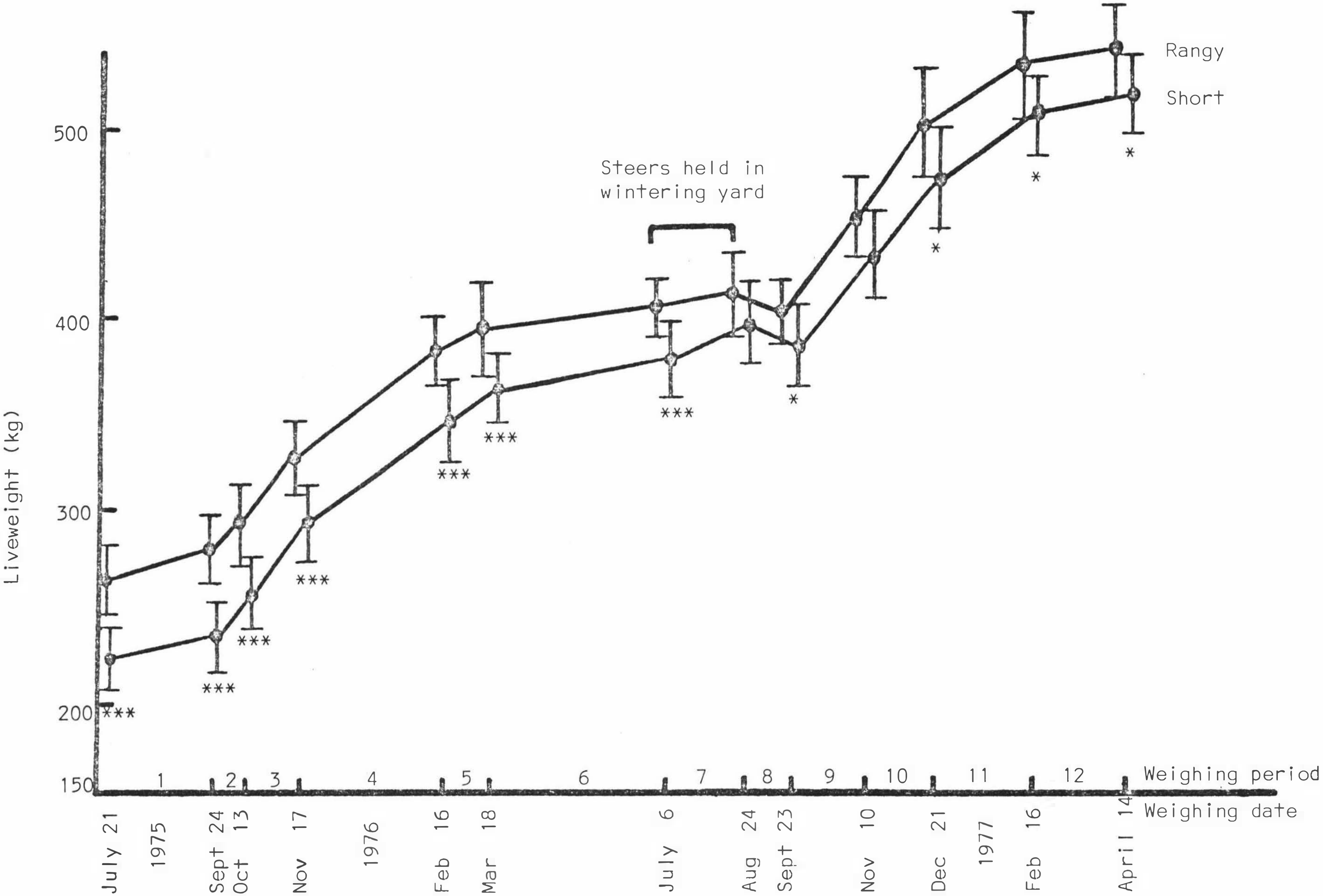

Fig. 4.4 Average liveweights and standard deviation bars for rangy- and short-type Angus steers in Trial XI *versus* weighing period and weighing date.

In contrast with the overall trend the rangy steers grew 0.25 kg/day faster than the short steers during period 10 (10 November - 21 December 1976), but the difference did not reach statistical significance at the 5% level of probability.

Short steers were more variable than rangy steers in average daily gain on nine of the twelve weighing periods, the ratio between the two groups was significantly different on only two occasions and then it was in the opposite direction.

Initial weight was not significantly correlated with final weight in rangy steers (r = 0.45, n = 15, n.s.) or in short steers (r = 0.41, n = 15, n.s.).

These results have to be interpreted in a similar manner to those for Beef Shorthorn types in Trial X, because each type was selected from a different herd and farm. The relatively high early growth rate of the short steers (except in the first weighing period) suggests there may have been some compensatory growth, or perhaps they had a greater genetic potential to grow over and above any nutritional weight restriction.

Mr P. H. Whitehead (pers. comm.) considered that the short steers had in fact been selected from a line of poorly-grown Angus weaners. The two groups of steers may have differed in average age or there may have been other factors affecting growth to weaning. The difference in age would have to be as great as calculated for Beef Shorthorn steers in Trial X (almost three months) and this was unlikely. The relative importance of other factors such as the effect of sire or dam cannot be determined. Therefore it would appear that differences in pre-trial environments between farms were sufficient to obscure differences in body shape related to growth rate.

This highlights the problem facing producers who select cattle on different farms or at sales without any records of performance.

Failure to distinguish between types could also be due to less variation in type in the Angus cattle on offer in contrast to Beef Shorthorn steers where it was known that there were large differences in the type of cattle produced in each herd.

Both mobs of Angus steers gained weight (rangy 9.1, short 20.1 kg) while held 49 days in a wintering yard and fed hay to a "maintenance" level. Short steers gained significantly more weight (11.0 kg $P < 0.05$) than rangy steers. Similar results were noted in Trial X in Angus steers (short > rangy), but not in Beef Shorthorn steers.

Trial XI - Types within Hereford steers

The two types of Hereford steers differed significantly in initial starting weight ($P < 0.01$), and on each weighing date except 16 February 1976 (Fig. 4.5, Table 4.11). Rangy steers were about 12% heavier than short steers throughout the trial which is a large difference within a breed.

The rangy group had a greater variation in liveweight than the short group, the ratio of within type variances was significant on the last three weighing dates.

Rangy steers grew 0.06 kg/day ($P < 0.001$) faster than short steers and put on 37.9 kg more liveweight over 633 days. This represents a substantial advantage in growth performance, as great as that recorded between Beef Shorthorn types in Trial X.

Brungardt (1969) found that rangy and leggy Hereford steers grew 0.32 kg/day faster than blocky and squat types. Crickenberger and Black (1976) reported that selected Herefords grew 0.30 kg/day faster than their unselected contemporaries. They cited the work of Brungardt (1972) where it was reported that rangy steers grew 0.26 kg/day more rapidly than short steers. These experiments were carried out in feedlots in the United States of America and did not cover as great a period of growth as in Trials X and XI. Results in Table 4.12 show a smaller advantage for rangy steers than has been reported in the literature.

There was a strong correlation between initial and final liveweight in rangy steers ($r = 0.69$, $n = 15$, $P < 0.01$) which indicates that these steers tended to rank in the same order of liveweight at the start and the end of the experiment.

Table 4.11 Means, differences and standard errors between the two types of Hereford steers for liveweight on each weighing date in Trial XI

Weighing date	Hereford Rangy n = 15 Mean (kg)	Hereford Short n = 15 Mean (kg)	Weight difference (Rangy-Short) (kg)	± SE (kg)
1975				
July 21	184.0	163.0	21.0 **	5.7
Sept 24	214.9	186.4	28.5 **	7.1
Oct 13	234.0	209.5	24.5 **	8.1
Nov 17	269.6	247.8	21.8 *	8.7
1976				
Feb 16	322.4	300.9	21.5	10.7
Mar 18	340.4	310.3	30.1 **	10.0
July 6	356.2	322.9	33.3 **	10.2
Aug 24	371.4	332.4	39.0 **	13.2
Sept 23	364.2	319.5	44.7 **	11.0
Nov 10	426.7	380.5	46.2 **	12.0
Dec 21	477.4	434.6	42.8 **A	12.9
1977				
Feb 16	512.0	462.1	49.9 **A	11.9
Apr 14	523.9	466.9	57.0 ***A	12.1

Table 4.12 Means, differences and standard errors between the two types of Hereford steers for average daily gain in Trial XI

Weighing period	Interval between weighings (days)	Hereford Rangy n = 15 Mean (kg/day)	Hereford Short n = 15 Mean (kg/day)	Difference in ADG (Rangy-Short) (kg/day)	± SE (kg/day)
1	65	0.47	0.36	0.11 *	0.05
2	19	1.01	1.21	-0.20	0.09
3	35	1.01	1.09	-0.08	0.08
4	91	0.58	0.58	0.00	0.05
5	31	0.60	0.31	0.29 *	0.11
6	110	0.14	0.11	0.03	0.03
7	49	0.30	0.18	0.12	0.09
8	30	-0.26	-0.46	0.20	0.14
9	48	1.30	1.27	0.03	0.08
10	41	1.24	1.32	-0.08	0.08
11	57	0.61	0.48	0.13	0.06
12	57	0.20	0.08	0.12 A	0.06
Overall	633	0.54	0.48	0.06 ***	0.01

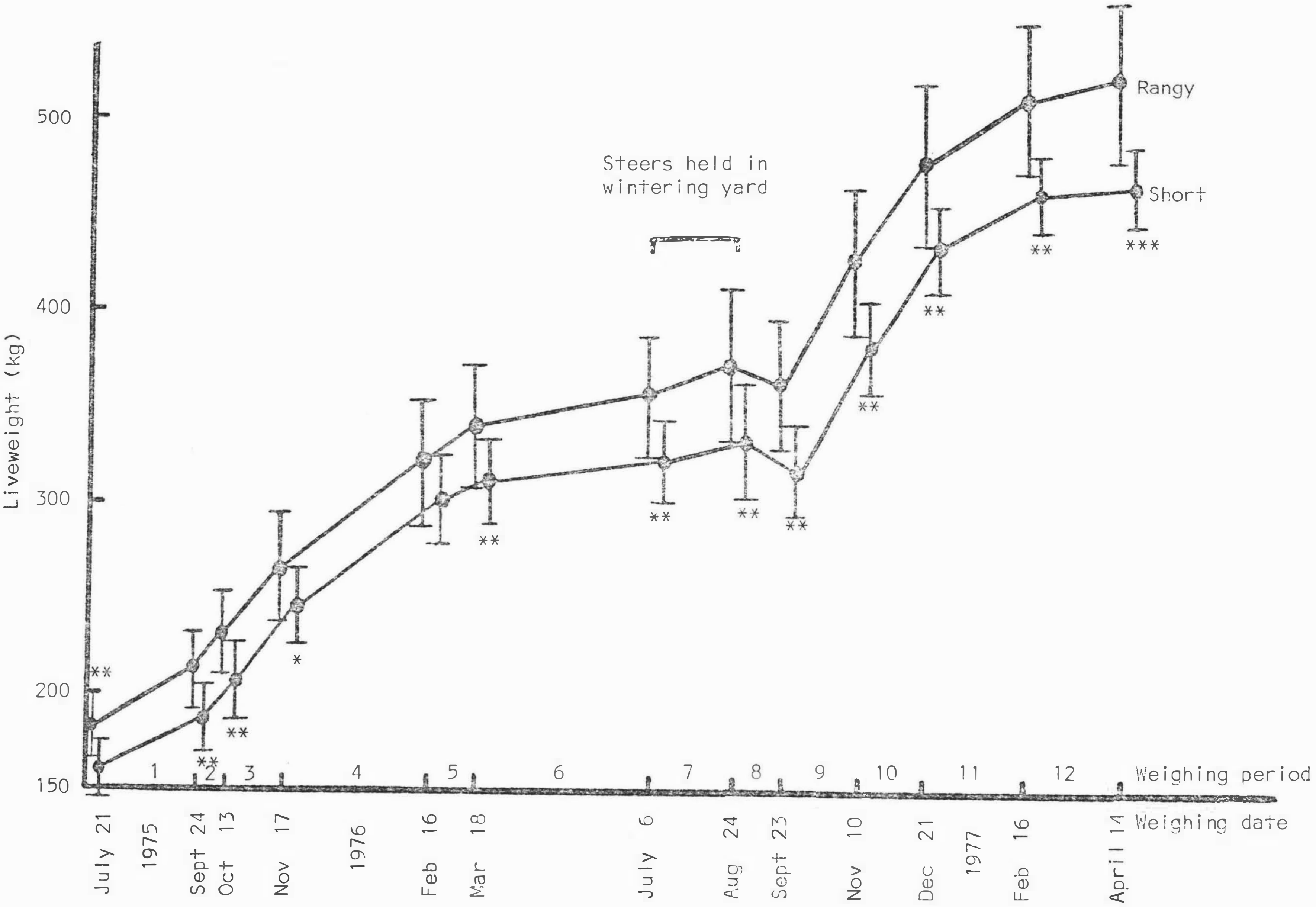

Fig. 4.5 Average liveweights and standard deviation bars for rangy- and short-type Hereford steers in Trial XI *versus* weighing period and weighing date.

The correlation in short steers was not significant r = 0.49.

Differences in initial liveweight were unlikely to have been caused by large differences in nutrition as the steers were in a similar environment. They may have varied in average age, but the selector would have had to choose steers for each group that were born 42 days apart on average (assuming a similar birthweight and growth rate of 0.5 kg/day to the start of the experiment). Age cannot be ruled out as a factor contributing to variation in liveweight, however its relative importance could not be assessed here. Age would not be expected to have accounted for the superiority of growth rate of rangy steers over the whole trial.

Other important factors such as the effects of sire and dam (genetic and environmental) could not be assessed.

Clearly the selection of two biological types by visual assessment was successful in terms of the growth performance of these steers. It is of interest that there was apparently greater variation in type in the Hereford than in the Angus steers. A similar result was noted in Trial X where Beef Shorthorn steers had a considerably wider range of type than Angus steers. Confounding factors including different selectors, different pre-trial environments and known differences in breeding policies mean that the observation that t-pe varied more in two breeds than in the other breed in this study could not be tested in a statistical sense.

Further work would be required to evaluate whether the small variation in type in Angus steers was genetic in origin, or due to difficulties in evaluating the shape of animals of this breed at, or about, weaning time.

Rangy Hereford steers gained 5.7 kg more weight (n.s.) in the wintering yard than short Herefords. Both types on liveweight (rangy 15.2 kg, short 9.5 kg) on the "maintenance" diet of hay. Liveweight gain in the wintering yard ranked: short Angus > rangy Hereford > short Hereford > rangy Angus, but differences were not tested statistically for reasons previously given.

Thus the use of a wintering yard was successful in both Trials X and XI as a means of maintaining the liveweight of steers during a period of pasture shortage when heavy cattle can cause pasture damage through pugging.

Trial XI - Comparison of Breed groups

Angus steers began the trial about 40% heavier than Hereford steers (Fig. 4.6). The difference between the two breed groups remained highly significant throughout the trial ($P < 0.001$). By the end of the trial, Angus steers were only about 8% heavier than Hereford steers because the Herefords had grown 0.05 kg/day ($P < 0.01$) faster than the Angus steers over the whole trial as can be seen in Table 4.13. This meant they gained 31.6 kg more liveweight than Angus steers over 633 days.

Table 4.13 Weighted means, differences and standard errors, between the two breed groups for average daily gain in Trial XI

Weighing period	Interval between weighings (days)	Angus n = 30 Mean (kg/day)	Hereford n = 30 Mean (kg/day)	Difference in ADG (Angus-Hereford) (kg/day)	± SE (kg/day)
1	65	0.17	0.42	-0.25 ***	0.04
2	19	1.03	1.11	-0.08 A	0.12
3	35	1.03	1.05	-0.02	0.05
4	91	0.60	0.58	0.02	0.03
5	31	0.54	0.46	0.08 A	0.10
6	110	0.11	0.13	-0.02	0.02
7	49	0.29	0.24	0.05	0.07
8	30	-0.38	-0.36	-0.02	0.10
9	48	1.00	1.29	-0.29 ***	0.05
10	41	1.10	1.31	-0.21 **	0.07
11	57	0.58	0.54	0.04	0.05
12	57	0.16	0.14	0.02	0.04
Overall	633	0.46	0.51	-0.05 **	0.01

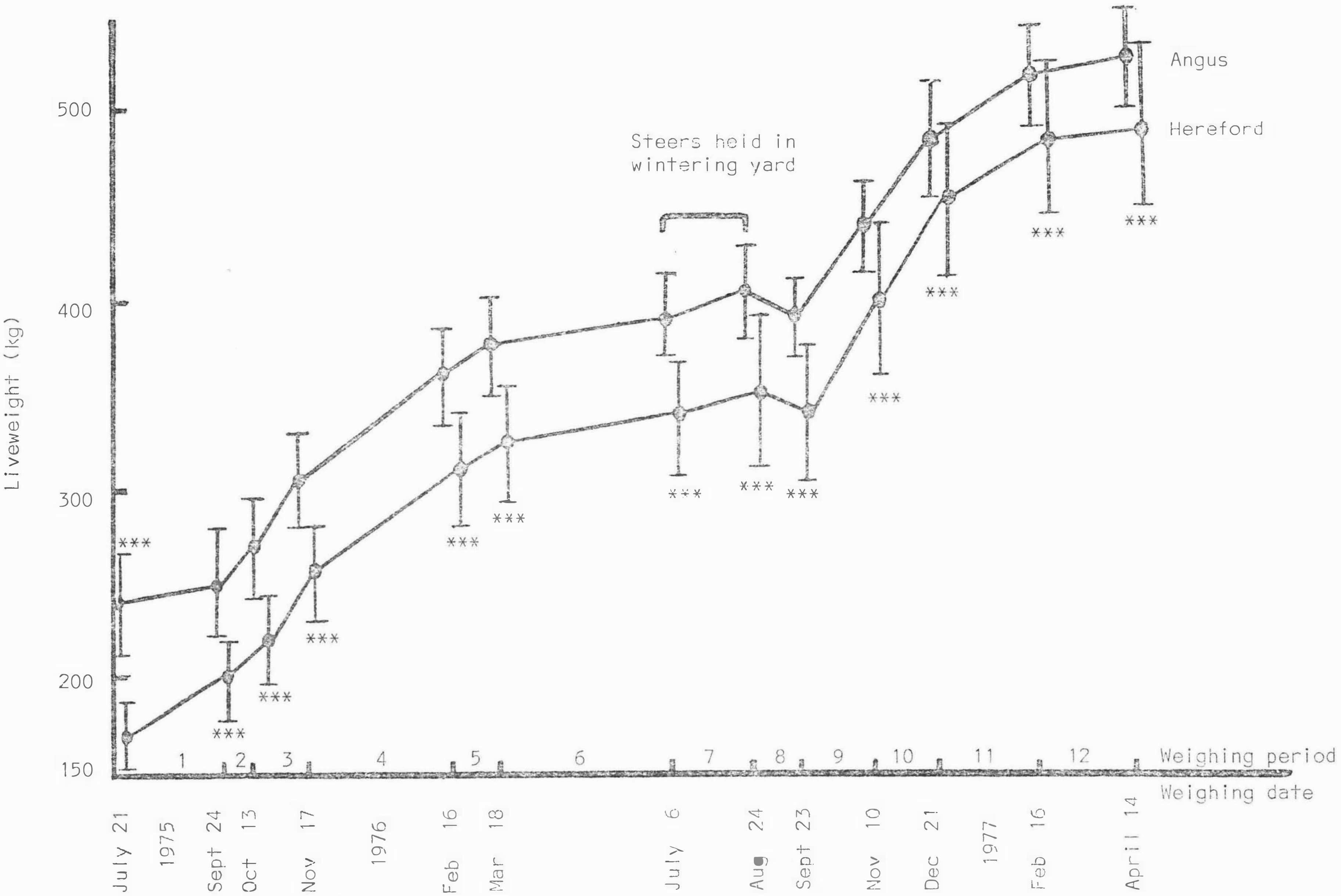

Fig. 4.6 Average liveweights and standard deviation bars for Angus and Hereford steers in Trial XI *versus* weighing period and weighing date.

A 40% difference in weight shortly after weaning between these Angus and Hereford steers would not be expected taking reports in the literature into account (Preston and Willis, 1974, Anderson, 1977). Therefore the difference must reflect pre-trial environmental differences as well as the effect of selection for different types (which was unsuccessful in the case of the Angus steers, but successful with the Hereford steers).

Previous studies at Massey University have not shown a consistent difference in growth rate between Angus and Hereford steers (Barton, 1966; 1968; 1972). Herefords grew faster than Angus (as in this experiment) in three of Barton's five trials. The difference between the breeds ranged from +0.04 to -0.07 kg/day (Angus-Hereford). The main purpose of Trial XI was to compare the performance of types within each of these two breeds rather than compare the breeds themselves.

The four groups of steers ranked: Hereford rangy > Hereford short > Angus short > Angus rangy, in terms of average daily gain over the whole trial. Type was nested within a breed so no statistical comparison was made across the four types. If it had been possible it is likely that only the difference between Hereford rangy > Hereford short would be significant.

4.3 Results of the analysis of carcass characteristics

Carcass characteristics of rangy and short Angus steers slaughtered in Trial X

The results in Table 4.14 show that there were no statistically significant differences ($P < 0.05$) between the two types of Angus steers in any of the carcass characteristics studied.

Rangy steers were 25.5 and 12.6 kg heavier in liveweight and carcass weight respectively than short steers, a superiority of 4.6% for carcass weight. Rangy steers yielded 4.5 kg ($P < 0.05$) more lean, 2.5 kg ($P < 0.01$) more bone and 0.9 kg (n.s.) less fat from the right side than short steers. Similar numbers of steers were graded either P1 or G in each type. Short type steers had 1.32% more excess fattrim and 2.0 mm more fat over the 12th rib than rangy steers but kidney and channel fat weight was almost identical in the two groups.

Rangy steers had larger eye muscle areas by 2.51 cm^2 than short steers, slightly longer carcasses by 2.41 cm, and long leg bones by 1.95 cm; (symphysis pubis to metatarsus) and 0.81 cm (radius ulna length). However, short steers had a similar carcass depth (chine to brisket despite being "shorter" in other measurements. This measurement was strongly influenced by carcass fatness and is probably due to slightly more fat present at the two measurement reference points in short carcasses. There was little difference in the ratio of carcass length to depth between the types and negligible differences in other carcass characteristics. The 0.82 and 0.58% increase in yield of trimmed bone and lean

Table 4.14 Carcass characteristics of rangy and short Angus steers slaughtered in Trial X

	Rangy Mean	Short Mean	Difference (Rangy-Short)	± SE
No. of steers in trial:				
At start	15	15		
At end	13	14		
Liveweight at slaughter (kg)	545.7	520.2	25.5	12.6
Dressing-out (%)	52.66	52.82	-0.16	0.42
Total carcass weight (kg)	287.4	274.8	12.6	8.0
Bone (%)	22.79	21.97	0.82	0.44
Fat (%)	15.36	16.68	-1.32	0.93
Lean (%)	61.45	60.87	0.58	0.94
Total kidney and channel fat (kg)	8.53	8.52	0.01	0.93
Depth of fat over the 12th ribeye (mm)	12.5	14.5	-2.0	1.5
Area of the ribeye at the 12th rib (cm^2)	67.09	64.58	2.51	2.54
Ratio lean : bone	2.72	2.76	-0.04	0.05
Symphysis pubis to first rib (cm)	127.42	125.01	2.41	1.21
Symphysis pubis to metatarsus (cm)	77.69	75.74	1.95	1.43
Length of radius ulna (cm)	37.72	36.91	0.81	0.48
Chine to brisket (cm)	70.12	70.21	-0.09	0.95
Carcass grade:				
P1	6	6		
G	7	8		

respectively in rangy steers was not significant or important, but was in the expected direction for later-maturing steers. Differences in carcass composition between types reflect the greater percentage of excess fat trim in short steers because the ratio of trimmed lean to trimmed bone was similar in the two groups (2.72 rangy, 2.76 short).

The 12.6 kg (n.s.) greater carcass weight of rangy steers raises the question whether or not the differences in carcass composition shown in Table 4.14 are more or less than would be expected given normal relationships between carcass weight and composition (Berg and Butterfield, 1976).

To remove the obscuring effect of carcass weight within a breed appropriate variables were adjusted to an equivalent right side weight of 141.8 kg by linear regression and tested for significant differences in an analysis of covariance as described in Chapter 3. The results of this analysis are presented in Table 4.15.

Analysis of covariance was used because it provided another way of examining these data. The results of this analysis have to be interpreted with caution. First, because the removal of a liveweight effect actually removes the type effect (rangy steers were heavier at the start of the trial and grew more rapidly during the trial than short steers). Secondly because of the small range of carcass weight covered by each type. Thirdly because the model was applied within a breed. Strictly speaking

Table 4.15 Carcass differences between rangy and short Angus steers in Trial X when adjusted to the same right side weight (141.8 kg)

	Difference between adjusted means (Rangy-Short)	± SE
Bone (%)	1.09 *	0.31
Fat (%)	-2.03 *	0.63
Lean (%)	1.05	0.68
Total kidney and channel fat (kg)	-0.72	0.59
Depth of fat over the 12th ribeye (mm)	-2.5	1.1
Area of the ribeye at the 12th rib (cm^2)	0.22	0.28
Symphysis pubis to first rib (cm)	1.34	0.75
Symphysis pubis to metatarsus (cm)	1.14	0.99
Length of radius ulna (cm)	0.39	0.29
Chine to brisket (cm)	-0.83	0.63

there should have been two randomly selected slaughter mobs in each type over a larger range of carcass weight than was possible in the experiment.

The slope, intercepts and homogeneity of within-type regressions were compared (for each carcass characteristic *versus* right side weight) and were generally not significantly different. (The results of these analyses are not presented here.)

Table 4.15 shows that the differences between types increased for all measures of carcass fatness when they were adjusted to the same side weight. Short steers were relatively fatter in each case and significantly more excess fat (2.03% $P < 0.05$) was trimmed from their fore- and hind-quarters.

Rangy steers had significantly more adjusted bone (1.09%, $P < 0.05$) and more adjusted trimmed lean (1.05%, n.s.) as a percentage of right side weight. This reflects the lower fat trim from these steers, because the difference in the ratio of trimmed lean to trimmed bone was not changed by regression on side weight (not presented in Table 4.15).

The difference between the types was reduced for most other carcass characteristics after regression on side weight (see ribeye area, symphysis pubis to first rib, symphysis pubis to metatarsus and radius ulna length in Tables 4.14 and 4.15). However, the difference was slightly increased for carcass depth indicating that short steers had slightly deeper carcasses.

The results of this analysis suggest that short steers were slightly earlier maturing than rangy steers and therefore had greater measures of carcass fatness at a similar side weight.

Brungardt (1972, cited by Crickenberger and Black, 1976), found large-framed Angus steers had 3.8% more fat in their carcasses than short-framed steers, but were also 6.66 kg heavier (his results were not adjusted for carcass weight therefore should be compared with those in Table 4.14). In contrast, Crickenberger and Black (1976) reported that average size Angus steers were leaner (2.02% less fat) than small steers although they had 40.8 kg heavier empty body weights.

Results of Trial X for carcass composition agree with those of Crickenberger and Black (1976) although there was little difference in the growth rates of the two types in Trial X compared with a superior growth rate of large-framed steers and average steers in the experiments of Brungardt (1972) and Crickenberger and Black (1976).

Carcass characteristics of rangy and short Beef Shorthorn steers slaughtered in Trial X

The results given in Table 4.16 show that rangy steers were 91.4 kg (19.5%) and 51.0 kg (20.7%) heavier in final liveweight and carcass weight respectively than short steers. These differences were highly significant ($P < 0.001$). There was no overlap in carcass weight between the two types of steers which ranged from 219 to 272 kg in short steers, and from 276 to 318 kg in rangy steers.

Table 4.16 Carcass characteristics of rangy and short Beef Shorthorn steers slaughtered in Trial X

	Rangy Mean	Short Mean	Difference (Rangy-Short)	± SE
No. of steers in trial:				
At start	15	15		
At end	14	15		
Liveweight at slaughter (kg)	560.0	468.6	91.4 ***	9.0
Dressing-out (%)	53.14	52.61	0.53	0.41
Total carcass weight (kg)	297.4	246.4	51.0 ***	5.9
Bone (%)	23.18	23.72	-0.54	0.52
Fat (%)	18.10	16.20	1.90 *	0.74
Lean (%)	58.36	59.53	-1.17	0.81
Total kidney and channel fat (kg)	8.61	6.88	1.73 *	0.68
Depth of fat over the 12th ribeye (mm)	9.9	11.4	-1.5	1.1
Area of the ribeye at the 12th rib (cm^2)	62.25	55.48	6.77 **	1.71
Ratio lean : bone	2.52	2.52	0.00	0.05
Symphysis pubis to first rib (cm)	127.86	120.23	7.63 ***	1.08
Symphysis pubis to metatarsus (cm)	80.21	72.95	7.26 ***	0.67
Length of radius ulna (cm)	38.89	35.84	3.05 ***	0.40
Chine to brisket (cm)	73.46	67.65	5.81 ***	0.77
Carcass grade:				
P1	3	8		
G	11	7		

This is an important result in commercial terms because increased carcass weight means a direct increase in gross monetary return to the prodcer unless carcasses are down-graded. The trade receives a greater weight of lean meat per beast which it can export, provided any increase in carcass fatness does not necessitate extra trimming to meet market specifications.

The extra yield from the right side of the carcass of rangy steers was; 6.8 kg ($P < 0.001$) more excess fat, 5.3 kg ($P < 0.001$) more bone and 13.3 kg ($P < 0.001$) more lean than short steers ($P < 0.001$).

The large difference in carcass weight between types makes it difficult to compare their carcass composition because of expected weight-related changes in composition due to the influence of carcass weight (Berg and Butterfield, 1976).

Rangy Beef Shorthorns had significantly more excess fat trimmed from their carcasses (1.90%, $P < 0.05$) and more kidney and channel fat (1.73 kg, $P < 0.05$). This would not be expected in a later-maturing type, but is probably a consequence of the greater carcass weight of the rangy steers. Rangy steers had 1.5 mm (n.s.) less fat depth over the ribeye at the 12th rib, a result consistent with their type, but not in relation to their greater carcass weight.

Eleven of the fourteen rangy steers, but only seven of the fifteen short steer carcasses were graded G. The grades do not reflect the small depth of fat over the 12th ribeye in rangy steers (P1 should range from 4 to 12 mm; G should range from 13 to 18 mm). A greater amount of excess fat would be expected to be trimmed from quarters of carcasses graded G and this was the case for rangy steers. (Some aspects of grading will be discussed later.)

Graders evaluate the distribution of subcutaneous fat over the carcass as well as a subjective estimate of fat depth when determining carcass grade. These apparently contradictory results presented here might therefore be due to a different distribution of subcutaneous fat in rangy steers and a change in the ratio of subcutaneous fat to other fat depots (especially intermuscular fat) between the two types of steers. Rangy steers had significantly larger eye muscle areas (6.77 cm^2, $P < 0.01$), less trimmed bone (0.54%, n.s.) and less trimmed lean meat (1.17%, n.s.) than short steers. These latter two results are in the expected direction taking into account changes in carcass composition that are related to carcass weight. There was no difference in the ratio of trimmed lean to trimmed bone between the types (rangy 2.52, short 2.52) which suggests that the differences in percentage yield presented above reflect a greater amount of fat trimmed from carcasses of rangy steers. A small increase in the ratio of trimmed lean to bone might have been expected in rangy steers corresponding with an increase in muscle to bone ratio as carcass weight increased. The yield of lean was probably influenced by increased carcass fatness and this might have altered the ratio of lean to bone. Rangy Beef Shorthorns had significantly greater ($P < 0.001$) carcass dimensions than short steers as would be expected (see Table 4.16). Only two measurements overlapped between types in carcass length (symphysis pubis to first rib), and radius ulna length, four measurements overlapped for chest depth (chine to brisket), no measurements overlapped for length of the leg (symphysis pubis to metatarsus). Despite the large differences in carcass dimensions there was little difference in the ratio of carcass length to depth between the two types of steers. Further analysis would be needed to evaluate whether or not this was due to normal associations between length and depth during growth of the body.

Carcass composition was adjusted to an equivalent right side weight of 136.7 kg (Table 4.17). Plots of the data indicated a linear relationship could be assumed and the slopes and intercepts of the within-type regressions were generally not dissimilar. Interpretation of these results requires caution for the reasons given for Angus steers in Trial X.

In this instance the adjusted mean lies outside the weight range of the type groups and a greater degree of extrapolation is involved than in Angus steers. Several texts (e.g. Snedecor and Cochran 1967, page 430) discuss the problems and limitations of such extrapolation. In the present case the weights of bone, fat and lean were regressed on side weight and then expressed as a percentage of that weight.

Table 4.17 shows there was a reduction in the difference between types for most variables (except fat depth over the ribeye at the 12th rib) when carcass composition was adjusted to the same right side weight.

Table 4.17 Carcass differences between rangy and short Beef Shorthorn steers in Trial X when adjusted to the same right side weight (136.7 kg)

	Difference between adjusted means (Rangy-Short)	± SE
Bone (%)	0.40	0.38
Fat (%)	-0.07	0.81
Lean (%)	-0.17	0.91
Total kidney and channel fat (kg)	-0.53	0.71
Depth of fat over the 12th ribeye (mm)	-5.1	2.1
Area of the ribeye at the 12th rib (cm^2)	2.77	1.80
Symphysis pubis to first rib (cm)	3.03	1.03
Symphysis pubis to metatarsus (cm)	3.74 **	0.59
Length of radius ulna (cm)	1.94 *	0.43
Chine to brisket (cm)	4.88 ***	0.28

Short steers had a greater depth of fat over the 12th ribeye (5.1 mm, n.s.), a similar percentage of excess fat trimmed from the right side (0.07%, n.s.) and slightly more kidney and channel fat (0.53 kg, n.s.). There was little difference between types in percent bone trim (0.40%, n.s.) and percent lean (0.17%, n.s.), between rangy and short steers. The decrease in the size of the difference between types was comparable to that in Angus types when they were compared at equal side weights and was expected as a consequence of normal carcass weight-composition relationships.

These results indicate that rangy Beef Shorthorn steers had a similar carcass composition to short steers at an equivalent carcass weight.

The increase in the difference between uncorrected and corrected means for subcutaneous fat depth at the 12th rib (short > rangy) is consistent with the suggestion that there may have been a difference in the distribution of subcutaneous fat over the surface of the carcass, or a change in the ratio of subcutaneous fat to intermuscular fat.

There was no significant difference between the two types of steers in ribeye area (2.77 cm, n.s.) or in the measure of carcass length (3.03 cm, n.s.) when these variables were compared at the same carcass weight.

Other measures of carcass dimensions remained significantly different with rangy steers exceeding short steers in length of the leg (3.74 cm, $P < 0.01$) radius ulna length (1.94 cm, $P < 0.05$) and carcass length (4.88 cm, $P < 0.001$). Rangy steers had slightly deeper carcasses in relation to carcass length, but the ratio was not statistically significant between types. The analysis of covariance results in Table 4.17 suggest that certain differences in carcass length can not be explained by the difference in right side weight between types. However, in adjusting carcass length to the same weight a part of the effect of type is also removed. The difference in initial liveweight and growth rate during the trial accounted for 54 and 46% respectively of the difference in final liveweight. These effects were removed in the analysis of covariance.

It must be remembered that all steers were slaughtered at the same time. This has unavoidably produced some anomalies. Rangy Beef Shorthorn steers for instance, were carried to a much higher carcass weight than would occur in most practical situations. Because of this they were over-finished and this adversely affected their carcass grading returns and measures of carcass fatness.

This is a common problem in research where different biological types of cattle are compared because the choice of an experimental end-point greatly influences carcass composition.

Carcass characteristics of Angus and Beef Shorthorn breed groups slaughtered in Trial X

Data from both types were combined in each breed group to give some indication of how the weighted differences between breeds compared with previous work at Massey University. This was done to give some relativity to the experiments reported here and not to evaluate breeds *per se*. Previous work at Massey University (Barton 1971a, 1972) found that Angus steers grew slower in one trial and faster in another trial than Beef Shorthorns. There was no difference in growth rate between the two breeds in Trial X. Angus steers were heavier than Beef Shorthorns at the start and end of the trial by 21.2 kg ($P < 0.01$) and 18.7 kg (n.s.). Table 4.18 shows Angus steers had similar carcass weights to Beef Shorthorns. Angus steers had slightly lower dressing-out percentages than Beef Shorthorns which agrees with Barton's studies (1971a, 1972).

The percentage yields of lean, excess fat and bone shown in Table 4.18 are similar to those reported by Barton (1971a, 1972), but of a lower magnitude. Angus steers yielded significantly more lean (2.6%, $P < 0.001$), less excess fat (1.0%, n.s.), less bone (1.09%, $P < 0.001$) and had a higher ratio of lean to bone (0.22, $P < 0.001$) than Beef Shorthorn steers. This is in agreement with previous work at Massey University. Angus had slightly more kidney and channel fat, and a significantly greater depth of fat over the ribeye at the 12th rib than Beef Shorthorns. These two

Table 4.18 Carcass characteristics of Angus and Beef Shorthorn steers slaughtered in Trial X

	Angus Mean	Beef Shorthorn Mean	Difference (Angus-Beef Shorthorn)	± SE
No. of steers at end of trial:	27	29		
Liveweight at slaughter (kg)	532.5	513.8	18.7 A	11.7
Dressing-out (%)	52.75	52.86	-0.11	0.29
Total carcass weight (kg)	280.8	271.6	9.2	6.9
Bone (%)	22.36	23.45	-1.09 ***	0.29
Fat (%)	16.10	17.10	-1.00	0.64
Lean (%)	61.20	58.60	2.60 ***	0.64
Total kidney and channel fat (kg)	8.52	7.74	0.78	0.65
Depth of fat over the 12th ribeye (mm)	13.7	10.8	2.9 **	0.9
Area of the ribeye at the 12th rib (cm^2)	65.80	58.77	7.03 ***	1.62
Ratio lean : bone	2.74	2.52	0.22 ***	0.05
Symphysis pubis to first rib (cm)	126.17	123.92	2.25 *A	1.09
Symphysis pubis to metatarsus (cm)	76.68	76.46	0.22	1.04
Length of radius ulna (cm)	37.30	37.31	-0.01 A	0.43
Chine to brisket (cm)	70.17	70.46	-0.29 A	0.81
Carcass grade:				
P1	12	11		
G	15	18		

results differ from previous studies where Angus had smaller measures than Beef Shorthorns (Barton, 1971a, 1972). The significantly larger ribeye areas of Angus steers (7.03 cm^2, $P < 0.001$) is of a similar order or magnitude to that reported by Barton (1971a, 1972) i.e., 4.4 cm^2 and 9.0 cm^2. Angus steers had significantly longer carcasses (2.25 cm, $P < 0.05$) and slightly longer legs (0.22 cm, n.s.). There was little difference between breeds in length of the radius ulna, but Beef Shorthorns had slightly deeper carcasses than Angus and a corresponding increase in carcass length to depth ratio.

The results for carcass composition and growth performance show that despite the selection for extreme types of Angus and Beef Shorthorn steers the breed means are similar to previously published work. In this respect the evaluation of types within a breed highlights the variability in phenotype in these Beef Shorthorns, and the apparent lack of it in the Angus steers in this study.

Carcass characteristics of rangy and short Angus steers slaughtered in Trial XI

Rangy steers had heavier final liveweights and carcass weights than short steers (21.2 kg, $P < 0.05$ and 14.3 kg, $P < 0.01$, respectively). They yielded 1.4 kg (n.s.) less excess fat trim, 1.9 kg ($P < 0.05$) more bone and 6.2 kg ($P < 0.001$) more trimmed lean from the right side than short steers. These results are commercially important to beef producers and the meat processor.

The results in Table 4.19 show that short steers appeared to be slightly earlier maturing in terms of carcass composition. A greater percentage of excess fat was trimmed from their right sides (1.74%, $P < 0.05$), and they had slightly more kidney and channel fat (0.87 kg, n.s.), but a similar depth of fat over the ribeye at the 12th rib (0.6 mm, n.s.).

Rangy steers yielded more trimmed lean (1.34%, n.s.) and more trimmed bone (0.25%, n.s.) than short steers reflecting a lower degree of fat trim. (The ratio of trimmed lean to bone did not differ significantly between the two types of steers: rangy 2.58, short 2.55).

Rangy steers had significantly larger ribeye areas than short steers (5.81 cm^2, $P < 0.05$), but carcass grade (Table 4.19) did not reflect the advantage rangy steers had in commercial yield. Most carcasses were graded P1 in each type. Rangy steers had significantly longer carcasses (2.12 cm, $P < 0.05$), and radius ulna lengths (0.75 cm, $P < 0.05$). There were small, non-significant differences between types in the circumference of the radius ulna (0.58 cm greater in rangy steers) and the length of the leg (1.19 cm longer in rangy steers).

The results are very similar to those observed in the Angus steers in Trial X in terms of carcass dimensions and carcass composition. They are in the expected direction for later-maturing rangy steers, but differences in composition are not large.

Table 4.19 Carcass characteristics of rangy and short Angus steers slaughtered in Trial XI

	Rangy Mean	Short Mean	Difference (Rangy-Short)	± SE
No. of steers at start and end of trial	15	15		
Liveweight at slaughter (kg)	540.8	519.6	21.2 *	8.9
Dressing-out (%)	51.16	50.47	0.69	0.41
Total carcass weight (kg)	276.3	262.0	14.3 **	4.5
Bone (%)	23.76	23.51	0.25	0.41
Fat (%)	14.41	16.15	-1.74 *	0.74
Lean (%)	61.27	59.93	1.34	0.78
Total kidney and channel fat (kg)	7.35	8.22	-0.87	0.71
Depth of fat over the 12th ribeye (mm)	11.9	11.3	0.6	1.0
Area of the ribeye at the 12th rib (cm^2)	69.48	63.67	5.81 *	2.38
Ratio lean : bone	2.58	2.55	0.03	0.04
Symphysis pubis to first rib (cm)	127.21	125.09	2.12 *	9.91
Symphysis pubis to metatarsus (cm)	77.47	76.28	1.19	0.64
Length of radius ulna (cm)	38.84	38.09	0.75 *	0.34
Circumference of radius ulna (cm)	38.17	37.59	0.58	0.52
Chine to brisket (cm)	68.46	67.69	0.77	0.94
Carcass grade:				
P1	13	13		
G	2	2		

A comparison of the carcass composition of both types of steers at the same right side weight (132.8 kg) is presented in Table 4.20.

The results given in the table agree with the suggestion that the short steers were earlier maturing than the rangy steers.

A greater percentage of excess fat was trimmed from carcasses of short steers, (1.73%, $P < 0.05$) which also had significantly more kidney and channel fat (1.72 kg, $P < 0.05$) than rangy steers. The difference between types in fat depth at the 12th rib was essentially unchanged when they were compared at the same side weight. This result also corresponds with that for excess fat trim.

Only two steers graded G in each of the two types of steers and this reflects the difference in fat depth between the P1 and G grades.

Differences between types in percent bone decreased (to 0.11%, n.s.) and percent lean increased (to 1.44%, n.s) when adjusted for the effect of right side weight. These results would be expected as normal changes in carcass composition associated with carcass weight (Berg and Butterfield, 1976).

There was no significant difference in ribeye area between rangy and short steers when adjusted for right side weight. Table 4.20 shows that the types did not differ significantly in any linear measurements, all differences were small when the traits were adjusted for carcass weight differences.

Table 4.20 Carcass differences between rangy and short Angus steers in Trial XI when adjusted to the same right side weight (132.8 kg)

	Difference between adjusted means (Rangy-Short)	± SE
Bone (%)	0.11	0.32
Fat (%)	-1.73 *	0.57
Lean (%)	1.44	0.60
Total kidney and channel fat (kg)	-1.72 *	0.50
Depth of fat over the 12th ribeye (mm)	0.4	0.8
Area of the ribeye at the 12th rib (cm^2)	1.94	1.49
Symphysis pubis to first rib (cm)	0.63	0.57
Symphysis pubis to metatarsus (cm)	0.20	0.41
Length of radius ulna (cm)	0.44	0.25
Circumference of radius ulna (cm)	-0.21	0.34
Chine to brisket (cm)	-0.44	0.64

Changes in carcass composition between Angus types in Trial X were related to a lower percentage of excess fat in rangy steers. Tables 4.19 and 4.20 show that in Trial XI rangy steers also had less excess fat trimmed from their carcasses, but they had a slightly greater ratio of lean to bone as well.

These results show that with the exception of measures of carcass fatness, there were small, generally non-significant differences in carcass composition between the two types of Angus steers. This agrees with results for Angus steers in Trial X. Significantly ($P < 0.05$) less excess fat was trimmed from rangy Angus carcasses as a percentage of carcass weight in both Trials X and XI (when adjusted for differences in right side weight). The general similarity of the order of differences in carcass composition of both types of steers in each trial contrasts with the results for growth rate. Rangy steers grew faster than short steers in Trial X, but not in Trial XI although the differences were not significant. It was suggested earlier that the more rapid growth rate of the short steers in Trial XI, especially in the first half of the period of the trial, could have indicated that compensatory growth was a factor. The types had been selected from different herds and the short group was considered to have been poorly grown. Carcass composition results above show that it was possible to select steers that were late-and early-maturing in terms of carcass composition, but not in terms of growth rate.

Carcass characteristics of rangy and short Hereford steers slaughtered in Trial XI

The results given in Table 4.21 show that rangy steers had significantly heavier final liveweights (56.9 kg, $P < 0.001$), and carcass weights (28.8 kg, $P < 0.001$) than short steers. In commercial terms, rangy steers yielded 2.7 kg ($P < 0.01$) more trimmed bone,[1] 5.3 kg ($P < 0.001$) more excess fat and 6.4 kg ($P < 0.01$) more trimmed lean than short steers. Within-type variances differed for these traits, but this was taken into account in tests of significance.

Brungardt (1969) reported similar trends in his comparison of five body types of Hereford steers. The types varied from blocky and squat to rangy and leggy. There was no difference in fat cover and ribeye area, but rangy and leggy steers yielded 71.7 kg more carcass weight and 31.3 kg more preferred cuts than short and blocky steers. They had 1.5% less round and 1.3% less cuts than short and blocky steers probably as a consequence of their greater carcass weight (Luitingh, 1962).

A significantly greater percentage of excess fat was trimmed from the carcasses of rangy steers. This would have been expected in relation to the difference in carcass weight between types, but not type *per se*.

It should be noted that the difference in carcass composition was greater in Herefords than in Beef Shorthorns (rangy cattle fatter than short cattle) and yet the Beef Shorthorn types differed by twice as much in carcass weight than did the two Hereford types.

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[1] From the right side of the carcass.

Table 4.21 Carcass characteristics of rangy and short Hereford steers slaughtered in Trial XI

	Rangy Mean	Short Mean	Difference (Rangy-Short)	± SE
No. of steers at start and end of trial	15	15		
Liveweight at slaughter (kg)	523.3	466.4	56.9 ***A	12.1
Dressing-out (%)	50.24	50.24	0.00	0.69
Total carcass weight (kg)	262.8	234.0	28.8 ***A	6.8
Bone (%)	24.38	25.10	-0.72	0.57
Fat (%)	17.25	14.81	2.44 **	0.75
Lean (%)	57.79	59.57	-1.78	0.83
Total kidney and channel fat (kg)	7.89	5.67	2.22 **A	0.69
Depth of fat over the 12th ribeye (mm)	8.5	7.7	0.8 A	0.8
Area of the ribeye at the 12th rib (cm^2)	53.86	57.63	-3.77	2.15
Ratio lean : bone	2.36	2.37	0.01	0.05
Symphysis pubis to first rib (cm)	125.57	119.93	5.64 ***A	1.24
Symphysis pubis to metatarsus (cm)	78.57	74.59	3.98 ***A	0.85
Length of radius ulna (cm)	39.42	37.75	1.67 ***	0.36
Circumference of radius ulna (cm)	37.40	36.68	0.72	0.48
Chine to brisket (cm)	69.38	65.79	3.59 ***	0.87
Carcass grade:				
P1	5	13		
G	10	2		

The 2.44% greater ($P < 0.01$) excess fat trim corresponds with carcass grades as does the 2.22 kg ($P < 0.01$) greater weight of kidney and channel fat in rangy steers. A higher proportion of rangy steers were graded G than short steers. Rangy steers were probably over-finished as a consequence of the experimental design and their superior growth rate. (See discussion for Beef Shorthorn steers.)

There was a comparatively small difference in the depth of subcutaneous fat between the types (0.8 mm, n.s.) and though it was in the expected direction (rangy > short) in relation to carcass weight differences, a larger difference might have been anticipated because of the greater percentage of excess fat trim, kidney and channel fat, and the incidence of G grade carcasses of the rangy steers.

The results shown in Table 4.21 show that rangy steers had a lower percentage of trimmed bone and lean than short steers. This result, though non-significant, reflects the greater percentage of excess fat trimmed from rangy steers because the two types had similar (2.37) ratios of trimmed lean to bone. The difference in the percentage of bone and lean between types would be expected as a consequence of the increased carcass weight of rangy steers (Berg and Butterfield, 1976).

Short steers had larger ribeye areas than rangy steers ($3.77\ cm^2$, n.s.). This was an unexpected result as ribeye area is usually greater in heavier carcasses (rangy steers had significantly heavier carcasses). It also differs from results in previous trials where rangy steers had larger ribeyes than short steers.

There were highly significant ($P < 0.001$) differences between the Hereford types in all linear measurements (with the exception of the circumference of the radius ulna) as expected in relation to the heavier carcass weights of rangy steers. The ratio length : depth did not differ significantly between types.

Within type variances of length from symphysis pubis to first rib, and length from symphysis pubis to metatarsus were significantly different ($P < 0.05$ and $P < 0.001$, respectively), indicating greater variation in the rangy group. This corresponds with variation in liveweight and carcass weight and was taken into account in the tests of significance.

The analysis of carcass composition shows rangy steers were fatter than short steers, had longer and deeper carcasses and were considerably heavier. The difference in carcass composition may have been due to the effect of carcass weight as well as of type.

Carcass characteristics of the two Hereford types were adjusted to the same side weight in an analysis of covariance, the results are presented in Table 4.22. The reduction in the difference between types for all carcass variables (except ribeye area) was expected given normal relationships between these variables and carcass weight.

Rangy steers had slightly greater measures of carcass fatness though differences were small and not statistically significant. The superiority of the ribeye area of the short steers increased from 3.77 cm^2 (n.s.) to 6.76 cm^2 ($P < 0.01$). An increase could have been anticipated in view of the superior ribeye area of short steers at a

Table 4.22 Carcass differences between rangy and short Hereford steers in Trial XI when adjusted to the same right side weight (123.1 kg)

	Difference between adjusted means (Rangy-Short)	± SE
Bone (%)	-0.39	0.46
Fat (%)	1.02	0.53
Lean (%)	-0.60	0.63
Total kidney and channel fat (kg)	0.53	0.46
Depth of fat over the 12th ribeye (mm)	0.0	0.6
Area of the ribeye at the 12th rib (cm^2)	-6.76 **	1.68
Symphysis pubis to first rib (cm)	1.75	0.68
Symphysis pubis to metatarsus (cm)	1.57	0.53
Length of radius ulna (cm)	0.93 *	0.26
Circumference of radius ulna (cm)	-0.49	0.32
Chine to brisket (cm)	1.00	0.50

lower carcass weight. In the other comparisons between types in Trials X and XI ribeye area increased with carcass weight, but rangy steers had larger ribeyes than short steers.

The figures in Table 4.22 show that rangy steers had slightly longer and deeper carcasses (n.s.). There was a small, but significant difference in radius ulna length between types (rang > short).

The comparison of rangy and short types in Angus (Trials X and XI) indicated rangy steers were leaner than short steers when carcass composition was adjusted for differences in carcass weight. The results for Hereford and Beef Shorthorn types show that their carcass composition was similar when adjusted for differences in carcass weight.

Carcass characteristics of Angus and Hereford breed groups slaughtered in Trial XI

Hereford steers grew at a faster rate than Angus steers throughout the trial (0.05 kg/day, $P < 0.01$), but their superiority in growth rate was not sufficient to make up the large difference in initial liveweight that existed between the breed groups, therefore the results given in Table 4.23 show that Angus steers had a significantly greater ($P < 0.001$) liveweight and carcass weight compared to Hereford steers.

Previous studies at Massey University (Barton 1966, 1968, 1972) showed that Hereford steers grew more rapidly than Angus steers in three out of five trials (see Table 2.3), but the difference in five trials ranged from +0.04 to -0.07 kg/day (Angus-Hereford). Herefords had heavier carcasses than Angus in four out of five trials, the difference ranged from +17.6 to -25.4 kg (Angus-Hereford).

The superior growth rate of Herefords reported here compares with results of three studies at Massey University, as does the difference in carcass weight as a consequence of initial liveweight.

The small and unimportant difference in dressing-out % (Table 4.23) probably reflects carcass weight changes because in Barton's experiments Herefords had higher dressing-out percentages than Angus steers.

Despite their heavier carcass weight Angus steers in the present study had a significantly greater percentage of lean meat (1.92%, $P < 0.01$), a lower excess fat % (0.75%, n.s.) and a significantly lower percentage of trimmed bone (1.11%, $P < 0.01$) than Herefords. They also had a significantly greater ratio of trimmed lean to bone than Herefords (by 0.20 units, $P < 0.001$). These results are similar to those in other studies at Massey University although the superiority of Angus steers over Herefords was not consistent in all the comparisons (see Table 2.3) and differences in carcass composition were not large.

Table 4.23 Carcass characteristics of Angus and Hereford steers slaughtered in Trial XI

	Angus Mean	Hereford Mean	Difference (Rangy-Short)	± SE
No. of steers at start and end of trial	30	30		
Liveweight at slaughter (kg)	529.8	494.4	35.4 ***A	9.3
Dressing-out (%)	50.81	50.24	0.57	0.39
Total carcass weight (kg)	269.2	248.4	20.8 ***A	5.0
Bone (%)	23.63	24.74	-1.11 **	0.35
Fat (%)	15.28	16.03	-0.75	0.58
Lean (%)	60.60	58.68	1.92 **	0.58
Total kidney and channel fat (kg)	7.78	6.78	1.00	0.53
Depth of fat over the 12th ribeye (mm)	11.6	8.1	3.5 ***	0.6
Area of the ribeye at the 12th rib (cm^2)	66.57	55.75	10.82 ***	1.70
Ratio lean : bone	2.57	2.37	0.20 ***	0.06
Symphysis pubis to first rib (cm)	126.15	122.75	3.40 ***A	0.94
Symphysis pubis to metatarsus (cm)	76.88	76.58	0.30 A	0.65
Length of radius ulna (cm)	38.47	38.58	-0.11	0.30
Circumference of radius ulna (cm)	37.88	37.04	0.84 *	0.36
Chine to brisket (cm)	68.07	67.58	0.49	0.71
Carcass grade:				
P1	26	18		
G	4	12		

Angus steers had much larger ribeye areas than Herefords ($10.82\ cm^2$, $P < 0.001$). This superiority was previously demonstrated in all other experiments at Massey University (Barton, 1966, 1968, 1972). The difference in eye muscle area in Table 4.23 was more than twice as great as that reported in Barton's work.

In comparing linear dimensions of the breed groups Table 4.23 shows Angus steers were slightly longer (3.40 cm, $P < 0.001$) and deeper (0.49 cm, n.s.) in carcass measurements than Herefords. Angus steers had a greater circumference of the radius ulna, but shorter radius ulna lengths, indicating they were short and stocky in the forearm compared to Herefords.

The breed comparison was made to evaluate whether or not selection for rangy and short types had changed the relative performance of the two breeds. Results in Table 4.23 and previous work by Barton (Table 2.3) show that it had not.

Carcass characteristics of steers in two export grades (P1 and G) in Trials X and XI

Steers slaughtered in Trials X and XI were graded either P1 or G. Descriptions of Export Grade Standards P1 and G which applied at the time of slaughter can be found in various publications (e.g. Anon., 1975a b, 1976; Frazer, 1975). Carcasses in the P1 grade are expected to have a high yield of export cuts requiring a minimum of trimming of excess fat. Carcass conformation should be "compact" referring mainly to characteristics of the leg. (There is no corresponding class in the P grade for "leggy" carcasses with a similar level of fat trim and depth of fat). Fat depth over the ribeye should fall in the range 4 to 12 mm. Carcasses graded G would normally require more trimming of excess fat than those in the P1 grade. There is no conformation class in the G grade, depth of fat over the 12th rib should fall in the range from 13 to 18 mm.

In terms of the function of grading and standards for these grades we could expect distinct differences between the grades in the depth of fat at the 12th rib, the percentage of excess fat trimmed from the carcass and the percentage of lean cuts. Where standards are specified, as in the case of fat depth, there should be no overlap between grades.

Tables 4.24 and 4.25 present results of an analysis which compared the means of various carcass characteristics in each grade. The number of carcasses in each grade was more balanced in Trial X than in Trial XI. The grades are presented as G-P1 for convenience because more of the differences were positive (in an arithmetic sense). Carcasses graded P1 were supposed to have more desirable carcass characteristics than carcasses graded G. They were worth 5c/kg and 6c/kg more to the producer than carcasses graded G in Trials X and XI, respectively.

Tables 4.24 and 4.25 show that steers graded G had heavier live and carcass weights in both trials, the difference was significant in Trial X.

Table 4.24 Carcass characteristics of two export grades, for steers slaughtered in Trial X

	G Mean	P1 Mean	Difference G-P1	± SE
No. of carcasses	33	23		
Liveweight at slaughter (kg)	531.6	507.8	23.8 *	12.0
Dressing-out (%)	53.06	52.45	0.61 *	0.29
Total carcass weight (kg)	282.1	266.7	15.4 *	7.0
Bone (%)	22.64	23.34	-0.70 *	0.32
Fat (%)	17.53	15.27	2.26 ***	0.58
Lean (%)	59.37	60.95	-1.58 *	0.67
Total kidney and channel fat (kg)	8.56	7.46	1.10	0.58
Depth of fat over the 12th ribeye (mm)	13.1	10.7	2.4 *	0.9
Area of the ribeye at the 12th rib (cm^2)	9.79	9.40	0.39	0.29
Symphysis pubis to first rib (cm)	124.92	125.03	-0.11	1.17
Symphysis pubis to metatarsus (cm)	76.82	76.19	0.63	1.06
Length of radius ulna (cm)	37.51	37.02	0.49	0.44
Chine to brisket (cm)	70.97	69.38	1.59	0.80

Table 4.25 Carcass characteristics of two export grades, for steers slaughtered in Trial XI

	G Mean	P1 Mean	Difference G-P1	± SE
No. of carcasses	16	44		
Liveweight at slaughter (kg)	524.8	507.5	17.3	11.5
Dressing-out (%)	50.40	50.58	-0.18	0.46
Total carcass weight (kg)	264.6	256.7	7.9	6.3
Bone (%)	24.16	24.18	-0.02	0.43
Fat (%)	15.19	16.93	-1.74 **	0.64
Lean (%)	60.12	58.40	1.72 *	0.70
Total kidney and channel fat (kg)	7.69	7.13	0.56	0.61
Depth of fat over the 12th ribeye (mm)	9.8	9.9	-0.1	0.9
Area of the ribeye at the 12th rib (cm^2)	8.84	9.71	-0.87 *	0.37
Symphysis pubis to first rib (cm)	125.32	124.14	1.18	1.16
Symphysis pubis to metatarsus (cm)	78.29	76.16	2.13 ***	0.67
Length of radius ulna (cm)	38.98	38.36	0.62	0.32
Circumference of radius ulna (cm)	37.34	37.50	-0.16	0.42
Chine to brisket (cm)	69.52	67.21	2.31 ***	0.74

Carcasses graded G had a higher dressing-out percentage than those graded P1 in Trial X (0.61%, $P < 0.05$), but a lower dressing-out in Trial XI (0.18%, n.s.) corresponding with the size of the difference in carcass weight. A slight superiority might be expected for carcasses graded G if they were fatter than those in the P grade because of the positive (though not necessarily causative) relationship between dressing-out % and carcass fatness.

The small non-significant advantage (0.39 cm^2, n.s.) in ribeye area of G grade carcasses in Trial X might be expected as a consequence of their heavier carcass weight (15.4 kg, $P < 0.05$). In Trial XI carcasses which graded P1 had significantly larger ribeyes than carcasses graded G although the difference was not great (0.87 cm^2, $P < 0.05$). There were only small differences in carcass dimensions between grades in Trial X despite the 15.4 kg difference in carcass weight. Carcasses graded G were slightly deeper (1.59 cm, n.s.) than carcasses graded P1. In Trial XI (Table 4.25) G grade carcasses were slightly longer (1.18 cm, n.s.) and had significantly longer legs (2.13 cm, $P < 0.001$) and were deeper (2.31 cm, $P < 0.001$) than P grade carcasses of similar weight. P1 carcasses were only slightly more "compact" than G carcasses if the measure of leg length serves as an indicator.

Carcasses graded G had heavier kidney and channel fat weights in both trials, although the difference was not statistically significant.

In summary it appears that in Trial X graders considered that carcasses of similar dimension, but greater weight, met the specification of the G grade on average, while in Trial XI they chose carcasses of slightly greater dimensions, but similar weight for the G grade.

The results presented in Table 4.24 show that in Trial X there was a significantly greater depth of fat over the 12th rib (2.4 mm, $P < 0.05$) in carcasses which graded G than in carcasses graded P1. However Figs. 4.7 and 4.8 show that there was a considerable variation in fat depth which was outside the range specified for the G grade. Sixty percent of carcasses that graded G in Trial X had fat depths lying outside the specified range, with one carcass having E grade specifications (Fig. 4.7). The situation was worse in Trial XI where carcasses graded G actually had lower average fat depths than those graded P1 (0.1 mm, n.s. Table 4.25). Eighty-eight percent of carcasses graded G in Trial XI had fat depths outside the grade specifications (Fig. 4.8).

Graders had more success in assessing fat cover with regard to P1 standards, the average values are within the specified range. Although 30% and 25% in Trials X and XI, respectively of carcasses which were graded P1 had fat values outside the grade specifications. However most of these were wrongly classified by only 1 or 2 millimetres. Thus it was apparently easier to classify "lean" carcasses than "fat" carcasses in relation to grade standards.

Table 4.24 shows that a significantly higher percentage of excess fat, and a lower percentage of lean were trimmed from carcasses graded G in Trial X. This corresponds with grade expectations. But completely contradictory results are noted in Trial XI (Table 4.25) where a significantly lower and higher percentage of fat and lean respectively was trimmed from carcasses graded G. There was little difference in the percentage of bone between the

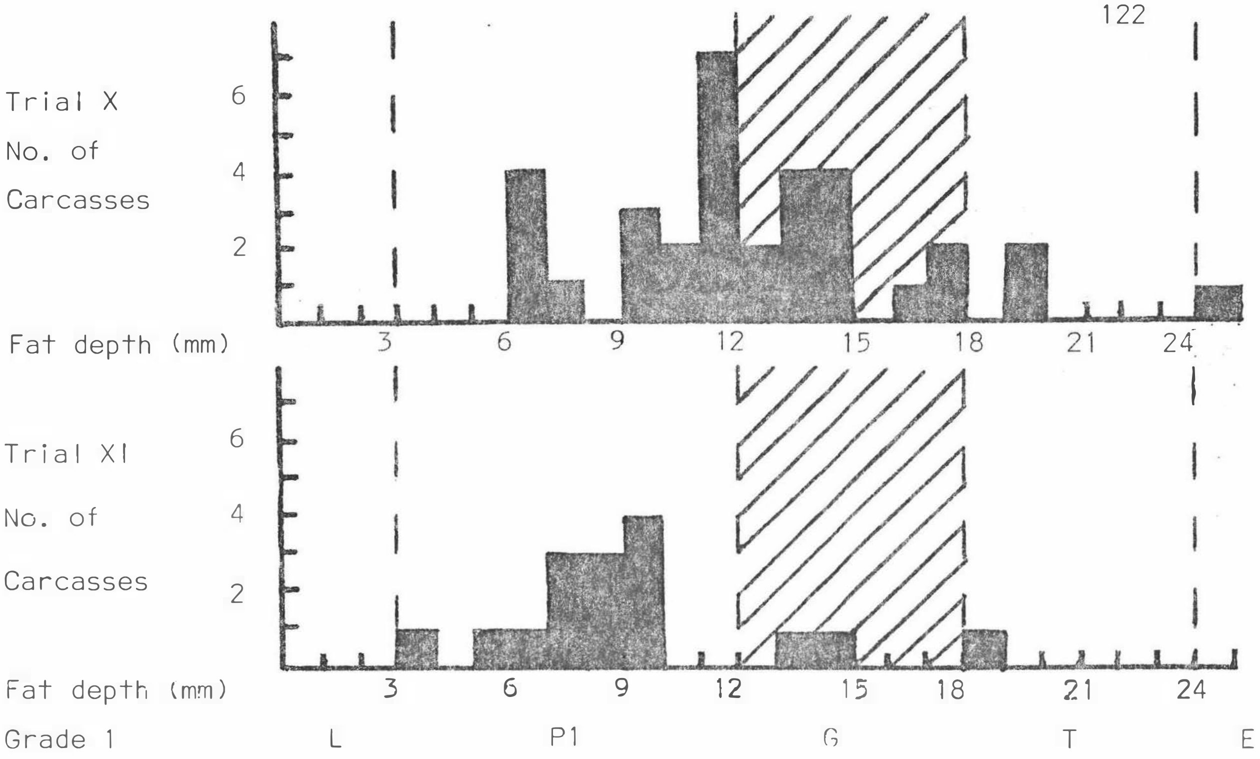

Fig. 4.7 Frequency distribution of carcasses graded G in Trials X and XI. Number *versus* fat depth at the 12th rib. All carcasses should lie within the shaded area (13-18 mm).

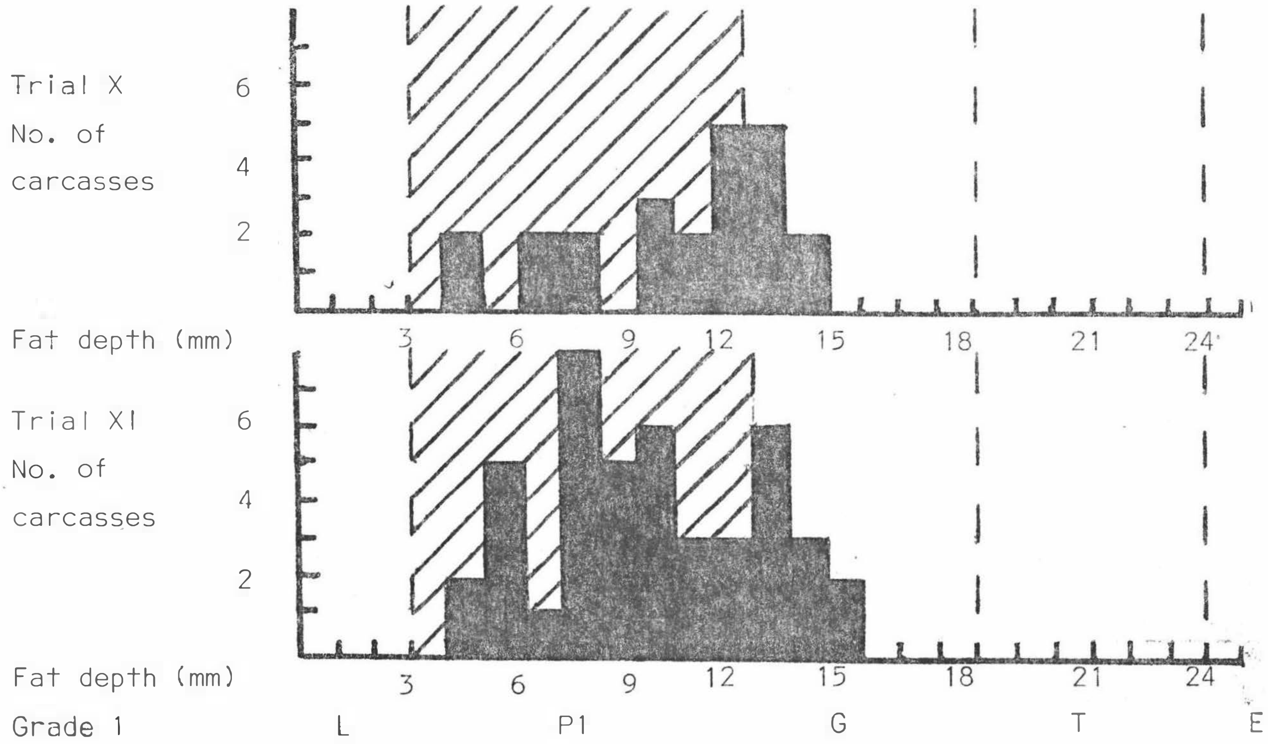

Fig. 4.8 Frequency distribution of carcasses graded P1 in Trials X and XI. Number *versus* fat depth at the 12th rib. All carcasses should lie within the shaded area (4-12 mm).

1 Export grade standards for fat depth: L = 1-3 mm, P1 = 4-12 mm, G = 13-18 mm, T = 18-24 mm, E = >24 mm.

grades in either trial although a significant, but small, difference was reported in Trial X. The significant difference in percentage lean tends to reflect the differences in excess fat trim in each case because carcasses in the two grades had similar lean to bone ratios.

In Trial X carcasses graded P1 were worth 5c/kg more than those graded G or $13.00 more for a 260 kg carcass. In Trial XI the advantage was 6c/kg or $15.60 more for a 260 kg carcass, yet in this trial carcasses graded G appeared to have superior carcass characteristics (see Table 4.25) in terms of the percentage yield, weight of lean and carcass weight.

The failure of the grading system to consistently identify carcasses with superior composition has serious implications for producers and the industry as a whole. A system that works on overs-and-unders cannot be expected to reward producers who set long-term goals in the production of cattle with superior carcass characteristics.

CHAPTER FIVE

CONCLUDING DISCUSSION

Selection of rangy steers resulted in increased beef production (yield of lean meat) in Angus, Beef Shorthorn and Hereford steers when compared to short-type steers of these breeds. There was, however, considerable variation in carcass composition in each type group.

The main reason for the increased yield of lean beef was the superior initial liveweight of rangy steers when selected at weaning. A secondary reason, of equal importance to the first in Beef Shorthorn and Hereford types, was the more rapid growth rate of rangy steers, which (because of the experimental design), resulted in rangy steers being over-finished. This adversely affected their carcass composition, but when the data were corrected for "normal" carcass weight/composition relationships there was little difference in the average composition of the type groups.

Doubt is cast on the validity of such an analysis of covariance because of the small range of weight within each type group and the extrapolation over the wider range of weight that existed between types.

Obviously if type is associated with growth rate then slaughter at a constant age would necessarily result in weight differences and weight related changes in composition. The analysis of covariance ignored this fact. Serial slaughter of randomly chosen steers in each type group would have provided a "better" estimate of weight related changes in composition.

Increased yield of beef in rangy Angus steers was not related to growth rate (no significant difference between types) but was related to selection of heavier steers at weaning. A secondary reason for increased beef production in Angus steers was that rangy steers were leaner than short steers. Differences in composition between types were not large, most being less than two percentage units. There was considerable variation in composition and carcass dimensions within each type.

The study provides evidence that visual selection for rangy, later-maturing types of steers, will improve production in the main beef breeds in New Zealand. The trend is in the right direction although improvement in terms of carcass composition may not be large, and the reasons for increased production various.

The importance of heavy weaning weight and its effect on subsequent growth and final weight have been reviewed by Preston and Willis (1974).

Factors known to affect weaning weight were reviewed by Preston and Willis (1974), Nicoll (1975) and Anderson (1977). Nicoll showed that variation in age at weaning accounted for up to 41.9% of variation in weaning weight in 7,770 Hereford weaners and 35.5% in 16,665 Angus weaners. Sex was the next most important source of variation. Variation between herds accounted for 15.6 and 15.0% of variation in weaning weight, respectively. Other main effects (age of dam, years) accounted for less than 10% of variation in weaning weight and most interactions less than 2%. The herd x year interaction accounted for 19.1 and 19.5% of weaning weight variation in Hereford and Angus herds.

Kennedy and Henderson (1975) reported that herds accounted for 24 to 41% of variation in weaning weight and from 31 to 44% of variation in yearling weight while other factors (years, sires, year-herd, year-sire) accounted for less than 10% of variation in weaning weight. Everitt, Jury and Ward (1975) showed a highly significant effect of pre-transfer environments on the subsequent weights of Friesian, Hereford x Friesian and Simmental x Friesian steers which were grazed on different farms to 16 weeks of age then transferred to a common environment. On average 97% of the difference in transfer liveweight persisted a year later.

Between herd differences are sources of variation in weaning weight in the Angus (Trial XI) and Beef Shorthorn types, but not in the Angus (Trial X) and Hereford types. Age, sire and dam effects were unknown. Barton (1967) and Preston and Willis (1974) reviewed the subject of live animal judgement and found that more "experienced" persons were able to discern between conformation types to a greater extent than less "experienced" ones.

In the present experiment the cattle were selected by experienced cattlemen, but as each type was selected (within a breed) by different people the opportunity existed for different interpretations of shape but this is an unknown factor here.

These results will be of use to cattlemen who have to select steers without access to performance records or liveweight measurements. Such purchases occur many times daily throughout New Zealand at saleyards and on farms when store cattle are bought solely on the basis of visual appraisal.

It is suggested that where possible the visual assessment of steers should be made in conjunction with performance records to evaluate animals on the basis of performance characteristics (weight and growth rate) and likely carcass composition.

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