ESTIMATION OF CARCASS COMPOSITION OF BEEF CATTLE BY THE UREA DILUTION TECHNIQUE

by

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I HEREBY CERTIFY THAT THIS RESEARCH IS THE RESULT OF MY OWN INVESTIGATION.

S.W. KOCK

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INTRODUCTION

A basic dilemma in meat production is the difficulty of estimating meat quality - as given by the proportion of muscle, fat and bone - without destroying the animal in the process, i.e. by slaughter. Nevertheless, this information is necessary if animals are to be produced and finished for the market in such a way as to yield the optimum amount of the best possible quality and quantity of product.

Research into methods of estimating carcass composition in the live animal is therefore of great practical importance. A considerable amount of data on carcass composition and the factors influencing the proportions of carcass components has been reported in the literature. Although a body of information is available on the composition of live animals at specified stages of development, there is still a need for a method which will permit the experimental evaluation of the composition of the live animal on a continuing basis as the animal passes through its various stages of development, and this without adversely affecting the animal or the product.

Early studies by Murray (1922) and Moulton (1923) showed that the water, protein and mineral content of the fat-free body become relatively constant when the animal has reached approximately 3,9 to 4,6 percent of its expected life span. These findings made it possible to estimate total body composition indirectly from either <u>in vivo</u> or <u>in vitro</u> measurements. Since then,

various methods for estimating body composition have been developed. These have not all been equally successful. Reid, Wellington and Dunn (1955) examined the relationships between the water, protein, fat and ash constituents of the bovine body and found that on a fat-free basis the whole empty body consisted of : water 72,91 $\pm$ 2,01 percent; protein 21,64 $\pm$ 1,53 percent and ash 5,34 $\pm$ 0,95 percent (means $\pm$ standard deviation). Gil, Johnson, Cahill, McClure and Klosterman (1970) cited a relatively constant average water content of 73,8 percent in the lean body mass of the bovine (range 69,3 to 75,8 percent). Preston, Vance, Cahill and Kock (1974) recently confirmed earlier work by Reid et al. (1955), obtaining similar constant relationships between the various chemical constituents of the bovine carcass when expressed on a fat-free basis. They reported values of 72,88% for water, 22,13 % for protein and 5,74% for ash.

Many workers have attempted to obtain significant relationships between live animal appraisal and carcass characteristics of beef cattle, but without any great degree of success (Wheat and Holland, 1960; Gregory, Swiger, Arthaud, Warren, Hallett and Koch, 1962; Davis, Long, Saffle, Warren and Carmon, 1964; Wilson, Dinkel, Tuma and Minyard, 1964; Gregory, Swiger, Breidenstein, Arthaud, Warren and Koch, 1964; Preston and Willis, 1974).

Gregory et al. (1962) reported that livestock graders could account for only approximately 20 to 25% of the variation in carcass characteristics on the basis of subjective scoring of

the live animal. Gregory et al. (1964) also investigated the relationship between the cutability estimated from the live animal and the actual cutability of the carcass of beef animals. They found that three experienced graders could, on the basis of live evaluations, account for only 35% of the variation in carcass cutability. Crouse, Dikeman and Allen (1974) reported that 37 to 44 percent of the variation in carcass traits could be accounted for by live-animal visual appraisal. Davis et al. (1964) found that livestock judges could not accurately predict muscling in beef cattle. Similarly, Wilson et al. (1964), using six independent livestock judges, reported low correlations between assessments of fat thickness, rib-eye area, percentage of kidney fat, dressing percentage and carcass grade made on the live animal and the actual results determined on the carcass. Nevertheless, some individuals with long experience of judging may successfully predict certain carcass traits in live animals (Preston and Willis, 1974). Lewis, Suess and Kauffman (1969) had previously examined the ability of experienced evaluators and of evaluators with little experience to predict carcass traits of market livestock and concluded that "more objective and accurate techniques of estimating carcass composition are needed, but until more refined, less expensive techniques are developed to satisfactorily meet this need, subjective appraisal will continue to play an important role in the evaluation of livestock for purposes of trade under commercial marketing conditions". This conclusion still remains valid at the present time.

Apart from visual appraisal, actual measurements on the live animal for purposes of predicting carcass characteristics have also been

investigated. The literature is well documented with reports showing the relationships between various live-animal measurements and beef carcass characteristics (Orme, Pearson, Magee and Bratzler, 1959; Good, Dahl, Wearden and Weseli, 1961; Bass, Palmer, Carpenter, Hentges, Wakeman, Koger and Murphy, 1962; Cundiff, Moody, Little, Jones and Bradley, 1967; Brackelsberg and Willham, 1968; Busch, Dinkel and Minyard, 1969).

Orme et al. (1959) investigated the relationships between live-animal measurements and various carcass measurements in beef cattle. When live mass was held constant, the circumference of the body measured at the fore flank gave a good direct relationship with rib-eye area, accounting for 81% of the variation in this parameter. Other live-animal measurements, such as circumference of the body at the rear flank, were less strongly related to rib-eye area, and accounted for only 20 to 33% of the variation in rib-eye area.

Good et al. (1961) compared live animal measurements with carcass traits in steers and concluded that width between the eyes, width of muscle, circumference of round and that of the cannon bone were significantly and negatively correlated with fat cover at the 12th rib. They obtained a correlation of -0,34 or less for all these parameters and fat cover at the 12th rib, and suggested that broad-headed, heavy-boned cattle with large rounds were desirable. The latter statement was rejected by Preston and Willis (1974) on the grounds that the correlations obtained accounted for only 11,6% of variation in fat cover.

For many years a comprehensive series of subjective determinations has been carried out on carcasses to assess muscling, meatiness, conformation and many other parameters, so as to assess the value of carcasses produced in nutritional, meat production, and breeding trials. In spite of the following quotation by Lush (1928), according to Warwick (1958a): "In geometrical sense the animal body is of such complicated shape that any one or a few measurements could approximate a description of it in only the crudest way", and his own conclusions, (Warwick, 1958b) "During the past 25 years or more a great deal of effort has been put into taking live animal and carcass measurements. To date I believe it must be admitted that they have been largely unproductive in developing methods for better evaluating animals in relation to their yield and cut-out qualities", many meat researchers persist in the measurement of carcasses of live animals in spite of certain criticism of other researchers and statisticians. Busch, Dinkel and Minyard (1969) evaluated live animal body measurements, subjective scores and estimates of certain carcass traits as predictors of edible portion in beef cattle carcasses. They reported that slaughter mass had the highest correlation with the edible portion in beef carcasses, and support Warwick (1958b) by maintaining that body measurements were of little value in predicting the edible portion of the carcass.

Brackelsberg and Willham (1968) examined the relationships among some common live-animal and carcass measurements and beef carcass composition. Use was made of probes to measure fat thickness taken over the <u>longissimus dorsi</u> muscle at the 12th rib in live

animals. The probing technique yielded as much information regarding carcass fat trim in the live animal (r = 0,67) as could be obtained from the 12th rib carcass fat thickness measurement (r = 0,64), which accounts for 45% and 41% of the variation in carcass fat trim and carcass fat thickness measurement, respectively. These results led to the conclusion that "the sets of carcass measurements were more precise than were the live measurements for predicting carcass composition; however, the sacrifice in precision perhaps is not large enough to warrant a progeny or sib test for selection if the heritability of the trait is high".

The use of dilution techniques to estimate body composition have been widely investigated. Tracer substances used in these techniques include deuterium and tritium-labelled water, antipyrine and its derivatives, potassium - 40 and many others. Although each of these markers has given satisfactory results under particular conditions, each suffers from its own special limitations. The tritium dilution technique is probably the most accurate method of estimating body composition in live animals and has been used in studies on rabbits (Reid, Balch and Glascock, 1958), man (Done and Payne, 1957), cattle (Aschbacher, Kamal and Cragle, 1965; Carnegie and Tulloh, 1968), sheep (Panaretto, 1968; Preston, 1969; Searle, 1970; Hofmeyer, Olivier, Kroon and van Rensburg, 1971; Meissner and Bieler, 1975) and pigs (Kay, Jones and Smart, 1966). However, apart from being a costly method requiring special equipment, the tritium-labelled water molecule also equilibriates relatively slowly in the body fluids - approximately 5-8 hours in sheep and cattle (Searle, 1970; Carnegie and Tulloh, 1968).

Furthermore, animals injected with tritium for experimental purposes are for some time after injection unfit for human consumption.

Several reports describe studies on the use of antipyrine as a predictor of total body water in man (Soberman, Brodie, Levy, Axelrod, Hollander and Steel, 1949), cattle (Kraybill, Hankins and Bitter, 1951; Wellington, Reid, Bratzler and Miller, 1956; Garrett, Meyer and Lofgreen, 1959; Whiting, Balch and Campling, 1960; Hansard, 1964) and sheep (Hansard and Lyke, 1956; Garrett et al. 1959). The method suffers from some distinct disadvantages, the main one being that antipyrine tends to be bound by plasma proteins (Soberman et al., 1949). A further problem is that it can be transported from the blood into the gastrointestinal tract of the ruminant either via the saliva or through the rumen wall (Whiting et al. 1960). Garrett et al. (1959) concluded that the antipyrine dilution technique was too variable to be used in estimating the body composition of the ruminant.

Gil et al. (1970) investigated predictors of carcass composition in cattle varying widely in live mass, and compared direct and indirect methods with actual carcass analysis. The direct method involved carcass specific gravity measurements whereas the indirect method made use of 4-acetamidoantipyrine (4-AAA), a derivative of 4-dimethylamino antipyrine (Brodie and Axelrod, 1950; Brodie et al. 1951). This compound has no binding properties with plasma proteins, is almost non-metabolizable, and is nearly totally recoverable from the body and urine (Reid, Balch and Head, 1957; Reid, Balch and Glascock, 1958). Gil et al. (1970) found the 4-AAA

water space to be significantly correlated with both body water (R^2 = 0,90) and body fat (R^2 = 0,80) in kg.

Panaretto and Little (1965) examined the relation between red cell volume and total body water in sheep. They made use of the Evans blue dilution technique to determine red cell volume and tritium dilution to determine total body water space. They concluded that red cell volume could, with reasonable accuracy, predict total body water and that the latter could then be used to calculate body composition.

Creatinine, a metabolite of creatine, is excreted in the urine and provides a useful means for predicting lean body mass (Brody, 1945). Lofgreen and Garrett (1954) investigated the relationship between creatinine excretion in the urine and lean carcass content of beef steers. They reported a correlation of 0,67 between creatinine excretion per unit of body mass and percentage of separable lean content of the ninth, 10th and 11th rib cuts. Van Niekerk, Reid, Bensadoun and Paladines (1963) in studies with sheep, established prediction equations for estimating protein, water and the fat-free mass in the empty body from creatinine excretion in the urine. Highly significant correlations were obtained between each of the abovementioned three parameters and urinary creatinine excretion. However, it was noted that creatinine excretion was affected by the type of diet fed to the animals. Large increases in protein intake increased creatinine excretion in the urine, whereas starvation resulted in a reduction in urinary creatinine output.

Attempts have also been made to use naturally-occurring isotopes

such as ^{40}K for the evaluation of body composition of live animals. Such methods have been reported by Zobrisky, Naumann, Dyer and Anderson, 1959; Lohman, Breidenstein, Twardock, Smith and Norton, 1966; Frahm, Walters and McLellan,1971; and Clark, Hedrick and Thompson, 1976. Clark et al. (1976) obtained high correlation coefficients when ^{40}K and live mass were used in conjunction to predict nitrogen, ether extract, water and gross energy of the carcass. They reported R^2 values of 0,87, 0,87, 0,84 and 0,84, respectively.

Methods for measuring backfat thickness and rib-eye area by means of ultrasonic techniques have been reported by various research workers using pigs (Hazel and Kline, 1959; Price, Pearson, Pfost and Deans, 1960; Price, Pearson and Emerson, 1960), sheep (Campbell, Stonaker and Esplin, 1959) and cattle (Stouffer, Wallentine and Wellington, 1959; Stouffer, Wallentine, Wellington and Diekmann, 1961; Hedrick, Meyer, Alexander, Zobrisky and Naumann, 1962; Watkins, Sherritt and Zeigler, 1967; McReynolds and Arthaud,1970a, 1970b ; and Gillis,Burgess, Usborne, Greiger and Talbot, 1973). McReynolds and Arthuad (1970a) made a comparison between two commonly employed ultrasonic techniques for the measurement of fat thickness in beef cattle. These techniques are known as the A-mode and the B-scan techniques. In the former, several ultrasonic probe readings are taken of backfat thickness. In the B-scan system, a Polaroid camera is used to record the output of a cathode ray tube in response to a sound-emitting transducer. It was concluded that fat thickness could be ultrasonically measured with acceptable accuracy. The same investigators (1970b) reported research work

on the rate of fat deposition and longissimus muscle growth at periodic intervals in cattle, estimated from the A-mode technique. The results suggest a curvilinear relationship between live mass and fat deposition and a linear relationship between live mass and longissimus muscle growth.

Gillis et al. (1973) compared the A-mode and B-scan techniques for the measurement of fat thickness and rib-eye area in cattle. From this work it was concluded that the two approaches gave equally good results for back-fat thickness, both with respect to precision and accuracy. In the hands of an experienced operator the A-mode was superior to the B-scan method for estimating rib-eye area, but the latter method had the advantage of yielding data more rapidly.

Alhassan, Buchanan-Smith, Usborne, Ashton and Smith (1975) reported useful equations to predict body composition, especially total body fat and energy, from the 9-11 rib cut composition together with carcass mass. Their equations were developed using Hereford and Aberdeen Angus cattle with empty body masses of between 180 and 435 kg.

The prediction equations given by Alhassan et al. (1975) are :

(i) Hereford steers -

$$EBF = -11,49 + 44,08\ RF + 0,22\ WCW$$

$$(R^2 = 0,96,\ CV = 10,07\%)$$

(ii) Aberdeen Angus steers -

$$EBF = -49,30 + 31,30\ RF + 0,50\ WCW$$

$$(R^2 = 0,94,\ CV = 9,40\%)$$

where E B F = Empty body fat

R F = 9 - 11 rib cut fat

WCW = Warm carcass weight

Naudé (1975) found that the prime rib cut (8 - 10 rib) gave the highest overall coefficient of determination (r = 0,97) for fat mass and fat percentage in carcasses of various degrees of finish, with a low coefficient of variation of 6,61 - 8,43%. Carcass fat could be satisfactorily predicted from the prime rib fat content by the use of the following regression equation :

$$Y = 3,23 + 0,89\ X \qquad (r = 0,97)$$

where Y = fat percent in carcass

X = fat percent in prime rib.

The relationships between carcass density and body fat and body water was demonstrated in guinea pigs (Rathbun and Pace, 1945), lambs (Garrett, Meyer and Lofgreen, 1959; Preston, Hutcheson, Hedrick, Jeremiah, Zobrisky and Krause, 1968) and cattle (Kraybill, Bitter and Hankins, 1952; Reid, Wellington and Dunn, 1955; Garrett and Hinman, 1969; Gil, Johnson, Cahill, McClure and Klosterman, 1970: Preston, Vance, Cahill and Kock, 1974). Garrett and Hinman (1969) compared carcass density with the composition and energy content of the carcass and the empty body and concluded that: "Carcass density was highly significantly correlated with the various chemical constituents of the carcass and the empty body. Correlation coefficients between carcass density and the chemical constituents of the empty body were -0,96, 0,93, 0,92 and -0,95 for percent fat, water and nitrogen, and energy, kcal/g, respectively".

Gil et al. (1970) investigated the relationships between carcass composition parameters and carcass specific gravity measurements. In these investigations carcass specific volumes were calculated using the following formula :

$$\text{Carcass specific volume} = \frac{1}{\text{carcass specific gravity}} \times \text{water specific volume}$$

Gil et al. (1970) arranged their data into six groups on the basis of fatness and found significant relationships between water, protein or fat percentages with carcass specific volume for carcasses with fat contents ranging from 30 to 42 percent. The correlations between percent ash and specific volume were significant in all but the leanest group (10 to 15 percent fat). It was suggested that in young animals carcass density was more dependent on bone growth than on any other tissues. When the data from all the carcasses were combined, significant coefficients of determination (R^2) of 0,74 0,74 0,79 and 0,65 between specific volume and percent water, protein, fat and ash, respectively, were obtained. Highly significant correlation coefficients were also obtained between percent empty body fat and carcass specific volume (R^2 = 0,88).

Recent work by Preston, Vance, Cahill and Kock (1974) on thirty six steers of varying live mass and degrees of fatness support the work by Garrett and Hinman (1969) and Gil et al. (1970), indicating highly significant correlation coefficients between carcass specific gravity and carcass composition. Correlation coefficients of 0,94, 0,89 and -0,96 between carcass specific gravity and water, protein and fat, respectively, were obtained.

Donovan and Brenner (1930) studied the effect of the intravenous injection of urea on the exchange of molecules between blood and tissues in man and demonstrated that equilibrium was reached within 3 minutes in blood and within 15 minutes in cellular and free water of the body. Other workers reported that the urea molecule equilibrates with body fluids within 1 hour in dog (Painter, 1940) and within 12 to 15 minutes in cattle (Preston and Kock, 1973; Bennett, Swiger and Preston, 1975). Soberman Brodie, Levy, Axelrod, Hollander and Steele (1949) pointed out that test substances, acting as tracers for body composition estimates should show an even and rapid distribution throughout the body water, should be non-toxic and not foreign to the body nor cause any physiological disturbances. Furthermore, tracer substances should be accurately and easily measurable in either whole blood or plasma and they should not be selectively stored, secreted or metabolized.

In studies with humans, San Pietro and Rittenberg (1953) reported that urea appeared to meet all the requirements of a satisfactory tracer, and urea space and deuterium oxide space were found to be similar in size. In 1973 Preston and Kock published data illustrating the significant relationships between urea space measurements and percentage empty body fat and percentage empty body water in cattle.

Bennett, Swiger and Preston (1975) reported a correlation coefficient of 0,71 between a single urea dilution measurement at

12 minutes after urea infusion and the specific gravity of beef carcasses. The findings suggest that the precision of this relationship was not increased by using both urea space together with live mass.

From the review of literature that has been presented and from practical problems experienced by producers, it is amply evident that an effective and reliable method for estimating the composition of live animals is urgently required in the interest of efficient beef production. The research work to be described was concerned with an evaluation of the urea dilution technique as a means of measuring the carcass composition of the live beef animal. Since visual appraisal is the traditional method of evaluating the beef carcass and since such an appraisal is not very satisfactory, the value of specific gravity in estimating carcass composition was also investigated. In addition, the usefulness of the prime rib analysis method of carcass evaluation was also examined.

To summarize, the experiments incorporated in this study were designed to investigate three main objectives :

(i) the time at which to measure urea spaces after infusion,

(ii) estimating body composition in live cattle from the urea infusion technique, and

(iii) to determine the relationships between carcass specific gravity and prime rib composition and body composition and to evaluate these parameters for estimating body composition in cattle.

MATERIALS AND METHODS

(i) Experimental animals

One hundred and fifteen animals of a cross between British Breed types and Dual Purpose Breed types were used in this experiment. All animals were purchased from the same farm in East Griqualand, and in terms of quality were reasonably representative of the type of beef animal reaching the market in Natal. After their arrival at the Stockowners Co-op Experimental Farm near Tweedie, Natal, the animals were allowed an adaptation period of approximately two weeks before the experiment was commenced.

Before the start of the experiment all animals were treated against internal parasites, received inoculation against blackquarter (Clostridium chauvoei) and botulism (Clostridium botulinum). Only minor health problems were encountered during the course of the experiment. A number of animals in both experimental groups showed evidence of mild bloating. Of the two animals which were lost from the experiment one died from peritonitis, the other from gallsickness (Anaplasmosis, Anaplasma marginale).

Two main groups of animals were used in this experiment. The first group consisted of 56 weaner calves with live mass ranging between 150 - 270 kg and a mean of 210 kg.

The second group comprised 59 older animals, approximately 20 months of age, with live masses ranging from 220 - 445 kg and a mean of 330 kg.

Eight weaner animals were randomly selected for slaughter at the commencement of the trial. The remaining 48 weaners were randomly allotted to six sub-groups of eight animals each. Two weaner calves died during the experimental period, leaving a total number of 46 animals for this group. Likewise,eight randomly selected yearlings were slaughtered at the commencement of the trial. The remaining 51 yearlings were randomly allotted to six sub-groups of eight animals each - three subgroups each had one additional animal.

(ii) Feeding and feed

All animals had access to an equal area of floor space and with decreasing numbers of animals due to slaughter, pens were closed off by means of partitions to ensure that the area available per animal remained the same throughout the trial.

All groups were fed ad lib. on a commercially available feeding ration (Meadows "Complete Steer Fattening Concentrate") and the daily feed intake was recorded for each group. Only those factors which relate to body composition will be dealt with in this report and no consideration

will be given to the nutritional aspects.

(iii) Slaughter procedure

The weaner group reached the second slaughter point 56 days after the initial slaughter date and thereafter groups of eight animals were slaughtered every 14 days, with the final group being slaughtered after 126 days of feeding. Eight animals of the second group were slaughtered 28 days after the initial slaughter date and thereafter groups were slaughtered every 14 days, with the final group being slaughtered after 98 days of feeding.

The mass of each animal destined for slaughter was determined on each of the last two days prior to slaughter and the average mass was used as final live mass. Measurements were made under standard conditions of food and water withdrawal for twelve hours.

(iv) Urea space measurements

Urea space measurements for each animal were determined one day prior to slaughter of each group using a technique described by Preston and Kock (1973). In brief, a polyethylene catheter (Clay Adams, PE 200) was inserted into the jugular vein through a No 12 needle. The needle was then removed and the catheter closed with a stopper. A solution containing 20% urea dissolved in 0,9% saline was

administered through the catheter over a two-minute period. The volume injected was accurately calculated to provide 130 mg Urea/kg live mass. The catheter was flushed with 5 ml saline and immediately thereafter with a heparin solution (100 units/ml saline) to prevent clotting between samplings. Blood samples were collected through the catheter prior to infusion, and at six, nine, 12, 15 and 18 minutes after the mean infusion time (Appendix 1).

The plasma, after centrifugation, was frozen for subsequent urea analysis. The methods described by Fawcett and Scott (1960) and Searcy, Gough, Korotzer and Bergquist (1961) were used to determine the plasma urea nitrogen (Appendix 2).

The following formula was used to calculate urea space as a percentage of live mass :

$$\text{Urea space (\%)} = \frac{\text{Volume infused}^{a} \times \text{concentration of solution}^{b}}{\text{PUN}^{c} \times \text{live mass in kg}}$$

a = volume of urea infused (ml)

b = concentration of urea solution infused (mg/100 ml)

c = difference in plasma urea nitrogen taken from blood sample prior to and after urea infusion.

(v) Carcass measurements

The animals were slaughtered by conventional means at the local municipal abattoir and the carcasses were split into halves. The warm carcasses were graded according to the South African grading system and the warm carcass masses

were recorded. After a chilling period of approximately 24 hours, the carcass specific gravity was determined according to the methods described by Garrett and Hinman (1969). The right side of the carcasses was quartered between the 7th and 8th ribs. This procedure of quartering a carcass is a normal practice under local abattoir conditions. The mass of each quarter was then determined in air and again under water using a balance positioned over a cylindrical tank (diameter, 120 cm; height, 200 cm). The temperature of the water was lowered by adding ice to the water until a water temperature of approximately 4^{o} C was attained. Both the temperature of the carcasses and of the water were accurately determined and recorded.

(vi) Sampling procedures

The prime rib cuts (8 - 10th rib) of the right side of each carcass were removed, their mass was recorded and they were then placed in plastic bags in which they were transported to the Department of Animal Science meat laboratory. For reasons of simplicity the term prime rib will be used throughout the dissertation to designate the whole prime rib cut (8 - 10 rib) of the right side of the carcass.

Six hours later the soft tissue from the prime ribs was completely dissected from the bone. The mass of bone and of soft tissue was separately recorded for each prime rib. The soft tissue which included muscle, fat and

connective tissue was thoroughly ground, placed in a plastic bag and frozen for subsequent analyses.

(vii) Analyses of prime rib cuts

Procedures for the analysis of the soft tissue were similar to those described by Morris and Moir (1963). After thawing and thoroughly mixing each sample, duplicate 100 g samples were placed in previously dried 250 ml glass beakers and dried at 95 to 100° C for 48 hours, by which time a constant mass had been attained. The loss in mass on drying was considered to be water. The sample-containing beakers were rewarmed in an oven to approximately 60° C, placed in a hood and the contents immediately covered with petroleum ether. After approximately 15 minutes the ether was decanted. This procedure was repeated three times on each sample, after which excess ether was evaporated at 95 to 100° C. The loss in mass due to the petroleum ether evaporation provided a preliminary fat value. The residue was ground through a Wiley mill using a 1 mm screen. Duplicate samples of the powdered material were used to determine dry matter, residual fat, nitrogen (Kjeldahl procedure) and ash, using A.O.A.C. (1965) procedures. The composition of each prime rib was then calculated using the appropriate mass and analytical data.

RESULTS AND DISCUSSION

The mean cold carcass masses of the weaner and yearling cattle used in the experiment, together with standard errors (S.E.) and ranges, are given in Table 1. The data relating to the chemical composition of the prime rib cuts, carcass specific gravity estimates and the results of the urea infusions which were carried out, are included in this table.

The number of animals in the weaner group was 54, and 59 animals represented the yearling group, giving a total of 113 animals for this investigation. The overall data are also shown in Table 1.

The cold carcass mass ranged from 105,0 kg to 261,5 kg in the weaner group of animals and from 138,0 kg to 349,0 kg in the yearling group, resulting in an overlapping of cold carcass mass between the two groups. Overlapping is also reflected in the prime rib composition between the two groups, especially with regard to the percentage fat, which ranged from 8,0 to 41,9 percent in the weaner group and from 10,7 to 42,5 percent in the yearling group of animals. The percentages of water, protein and ash in the prime rib were similar for the two groups of cattle.

It is also evident from Table 1 that carcass specific gravity fell within a similar range for the two groups. The slightly

Table 1. Means, standard errors and ranges of cold carcass mass, prime rib composition, carcass specific gravity data and urea space (as % of live mass) at various times after urea infusion for weaner and yearling cattle.

Item	Weaners			Yearlings			Overall		
	Mean	± S.E.	Range	Mean	± S.E.	Range	Mean	± S.E.	Range
Cold carcass mass (kg)	173,0	4,64	105,0 - 261,5	227,7	7,01	138,0 - 349,0	201,5	4.97	105,0 - 349,0
Prime rib composition :									
% water	61,8	0,88	43,0 - 72,0	59,4	0,86	42,5 - 69,0	60,5	0,62	42,5 - 72,0
% protein	17,4	0,13	14,3 - 19,0	17,2	0,16	14,5 - 19,6	17,3	0,10	14,3 - 19,6
% fat	19,8	1,00	8,0 - 41,9	22,4	1,04	10,7 - 42,5	21,5	0,73	8,0 - 42,5
% ash	0,8	0,02	0,6 - 1,2	0,8	0,02	0,6 - 1,2	0,8	0,01	0,6 - 1,2
100 (S.G.* - 1)	7,42	0,08	5,65 - 8,50	7,47	0,12	5,50 - 9,27	7,45	0,07	5,50 - 9,27
Urea space (%) at various times after urea infusion (min)									
6	48,0	0,62	39,7 - 55,3	44,0	0,55	34,0 - 52,2	45,9	0,45	34,0 - 55,3
9	51,7	0,62	42,8 - 61,1	48,5	0,53	38,0 - 56,1	50,0	0,43	38,0 - 61,1
12	53,8	0,58	44,4 - 62,7	51,7	0,51	42,6 - 59,2	52,7	0,39	42,6 - 62,7
15	56,4	0,59	46,0 - 63,8	54,5	0,51	44,7 - 62,8	55,4	0,39	44,7 - 63,8
18	59,2	0,66	48,9 - 68,7	57,3	0,56	46,3 - 69,1	58,2	0,43	46,3 - 69,1
No. of animals	54			59			113		

* S.G. = Specific gravity

greater range in specific gravity values for the yearling group suggests that this group had both leaner and fatter animals than were present in the weaner group.

The results in Table 1 demonstrate further that the percentage urea space at various times after urea infusion of the weaner group shows a gradual increase in mean value from 48,0 percent at 6 minutes to 59,2 percent at 18 minutes following urea infusion. The yearling group of cattle shows a similar increase in mean percentage urea space values with time, although the values are somewhat lower than in the weaner group; mean values ranged from 44,0 percent at 6 minutes to 57,3 percent at 18 minutes after urea infusion. The range of percentage urea space at various times after urea infusion also shows a gradual increase with time for both the weaner and yearling group of cattle.

(i) Optimum sampling time after urea infusion

(a) Effect of age of animal

The results in Table 2 show the correlation coefficients between urea space (as a percentage of live mass at various times following urea infusion) and the chemical constituents in the prime rib of weaner and yearling cattle. The correlation coefficient between urea space and the percentage of water in the prime rib was highest at 12 minutes after urea infusion, i.e.,

Table 2. Correlations between urea space (as a % of live mass and for various times after urea infusion) and the chemical constituents in the prime rib of weaner and yearling cattle.

Time after urea infusion (min)	Weaners				Yearlings				Overall			
	water	protein	fat	ash	water	protein	fat	ash	water	protein	fat	ash
6	0,82	0,77	-0,83	0,55	0,62	0,52	-0,60	0,42	0,72	0,60	-0,71	0,46
9	0,86	0,79	-0,87	0,58	0,68	0,57	-0,67	0,42	0,77	0,64	-0,76	0,50
12	0,91	0,80	-0,91	0,64	0,76	0,69	-0,76	0,52	0,84	0,73	-0,84	0,58
15	0,86	0,76	-0,86	0,60	0,72	0,63	-0,71	0,44	0,80	0,67	-0,79	0,52
18	0,80	0,70	-0,81	0,60	0,68	0,60	-0,68	0,40	0,75	0,64	-0,75	0,51

0,91 and 0,76, respectively, for weaner and yearling cattle, and 0,84 overall. The results are illustrated in Fig. 1.

Correlations between urea space and the percentage protein in the prime rib were also highest 12 minutes after urea infusion. Values obtained were 0,80 and 0,69 for the weaner and yearling groups, respectively, giving a correlation coefficient of 0,73 overall. This relationship at 12 minutes after urea infusion time is shown graphically in Fig. 2.

From Table 2 and Fig. 3 the results show highly significant correlations between urea space as a percentage of live mass and the percentage of fat in the prime rib for all the sampling times, 12 min. sampling time showing the highest correlation. For the weaner group this correlation coefficient was -0,91 and for the yearlings -0,76. The overall correlation coefficient was -0,84.

The scatter diagrams (Figures 4, 5 and 6) illustrate the relationships between urea space as a percentage of live mass measured at 12 minutes following urea infusion and the percentage of fat in the prime rib for the weaner, yearling and overall groups, respectively.

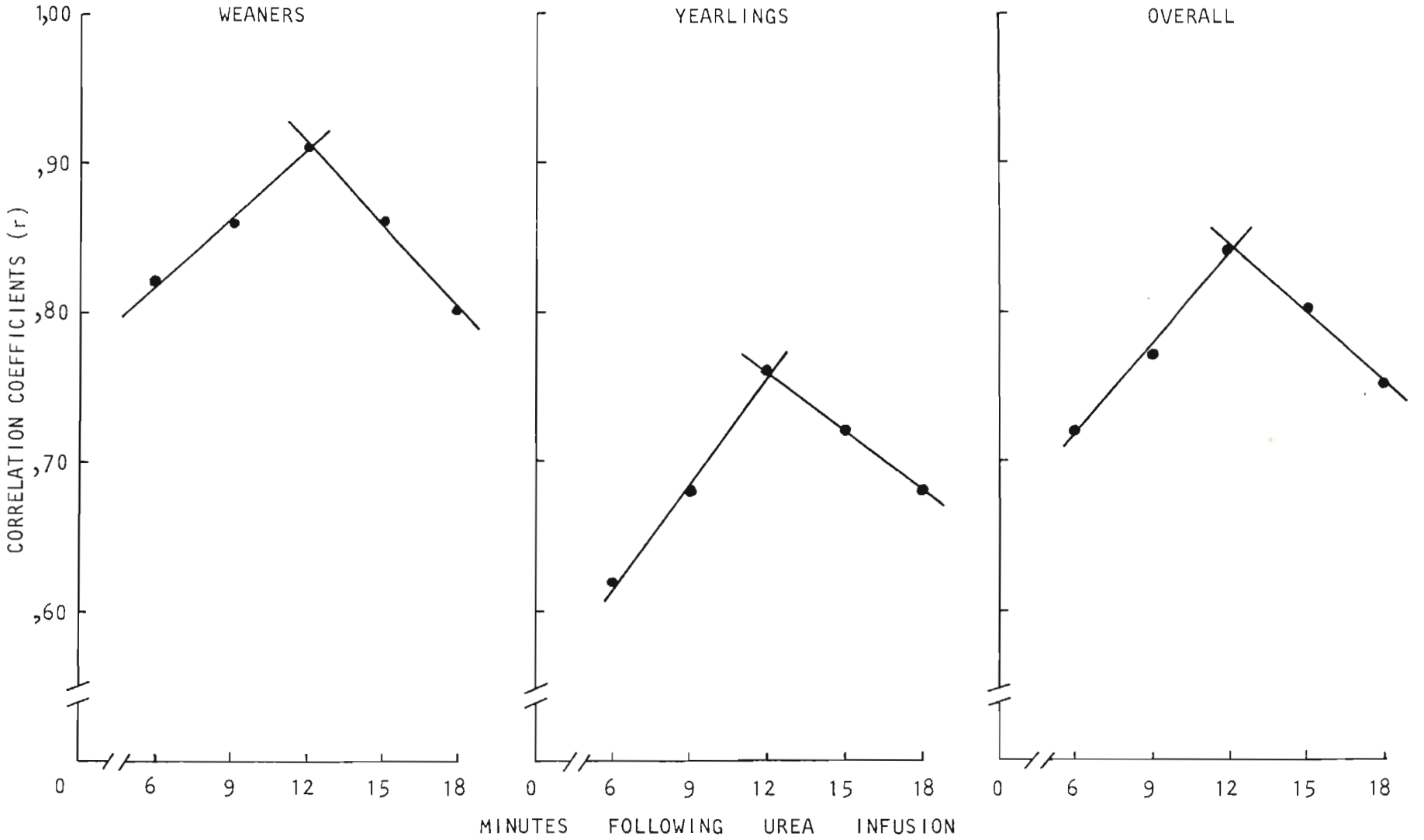

Fig. 1. Correlation coefficients between urea space (as a % of live mass, and for various times after urea infusion) and the percentage water in the prime rib of weaner and yearling cattle.

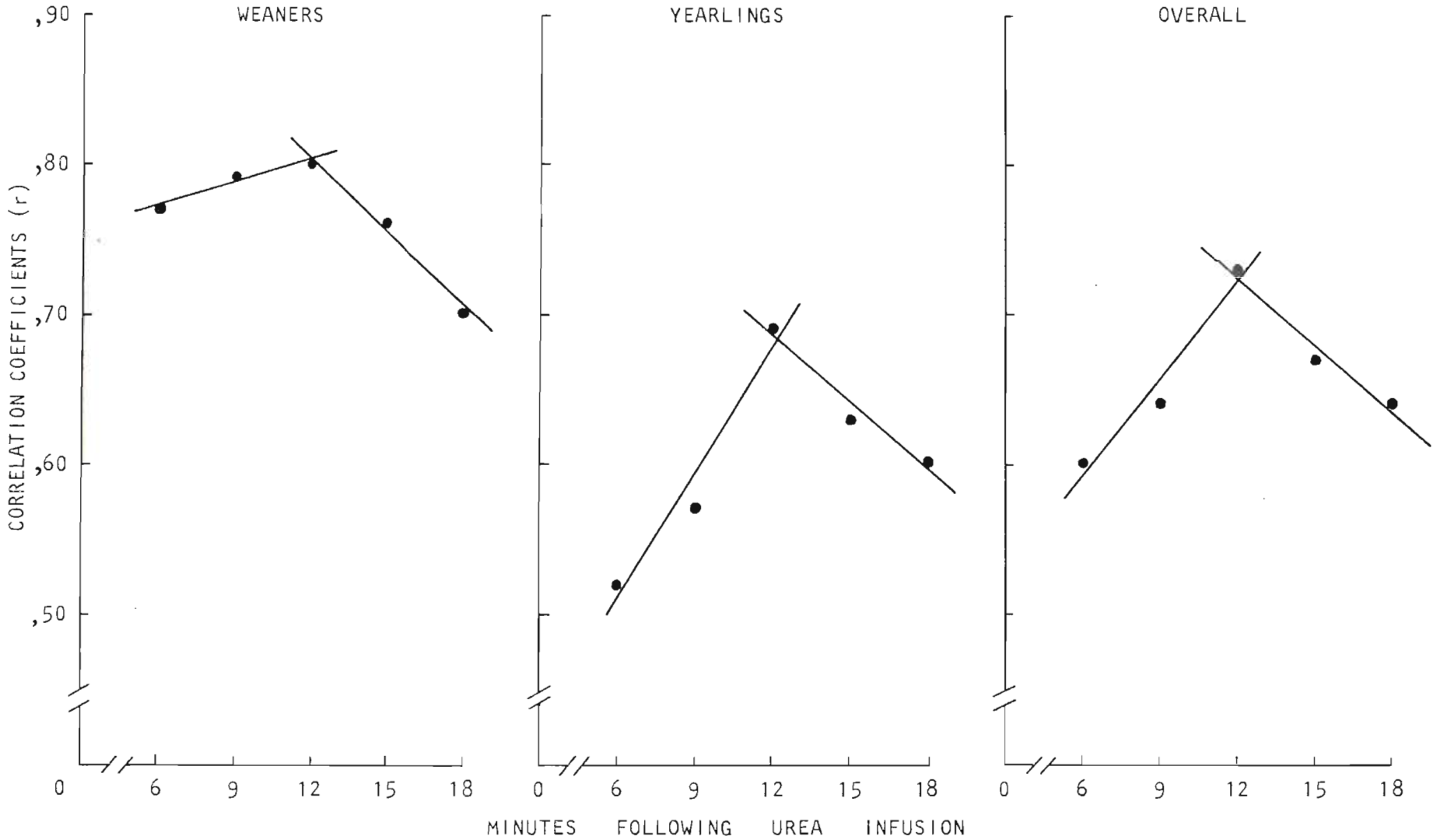

Fig. 2. Correlation coefficients between urea space (as a % of live mass, and for various times after urea infusion) and the percentage protein in the prime rib of weaner and yearling cattle.

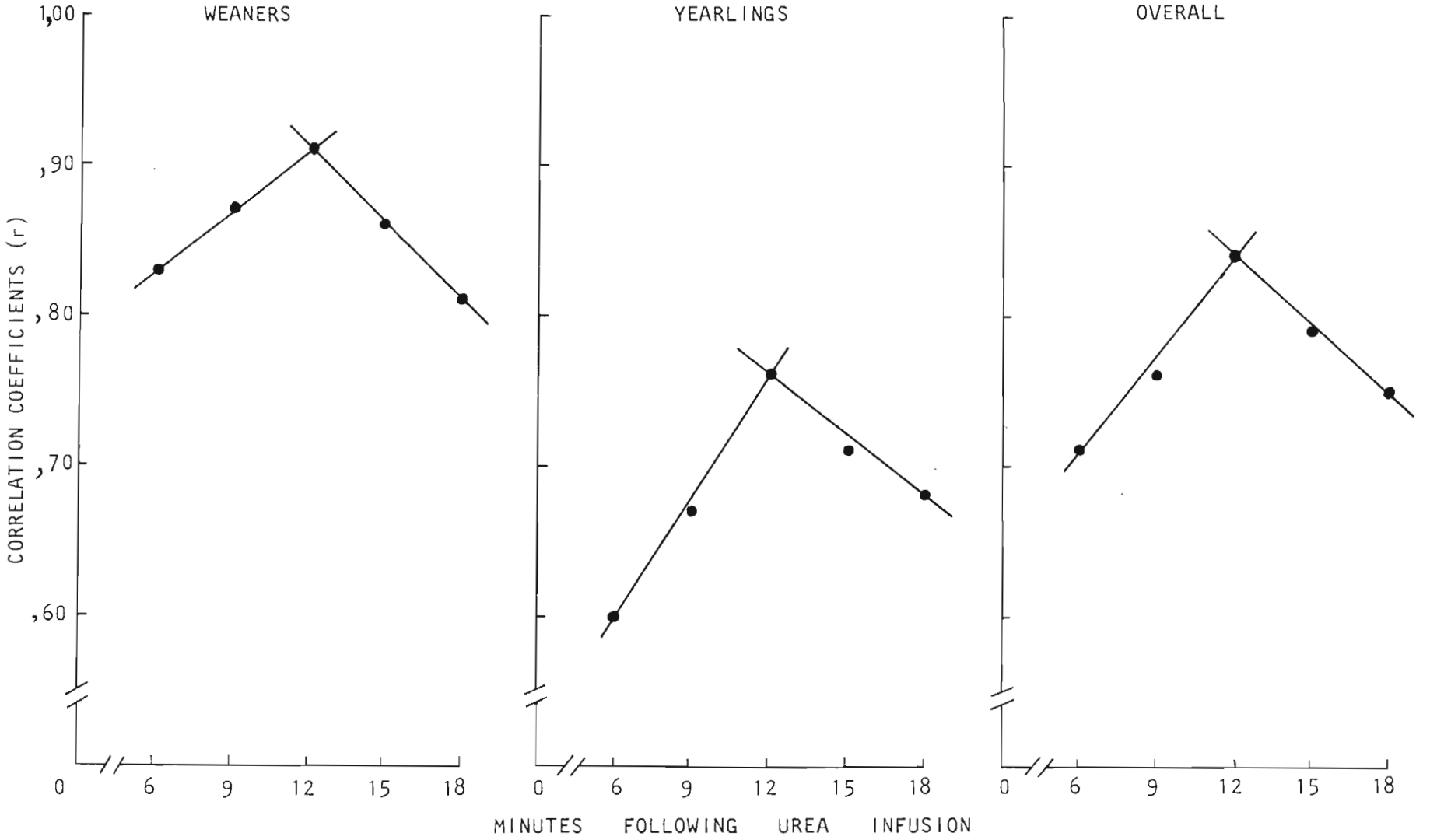

Fig. 3. Correlation coefficients between urea space (as a % of live mass, and for various times after urea infusion) and the percentage fat in the prime rib of weaner and yearling cattle.

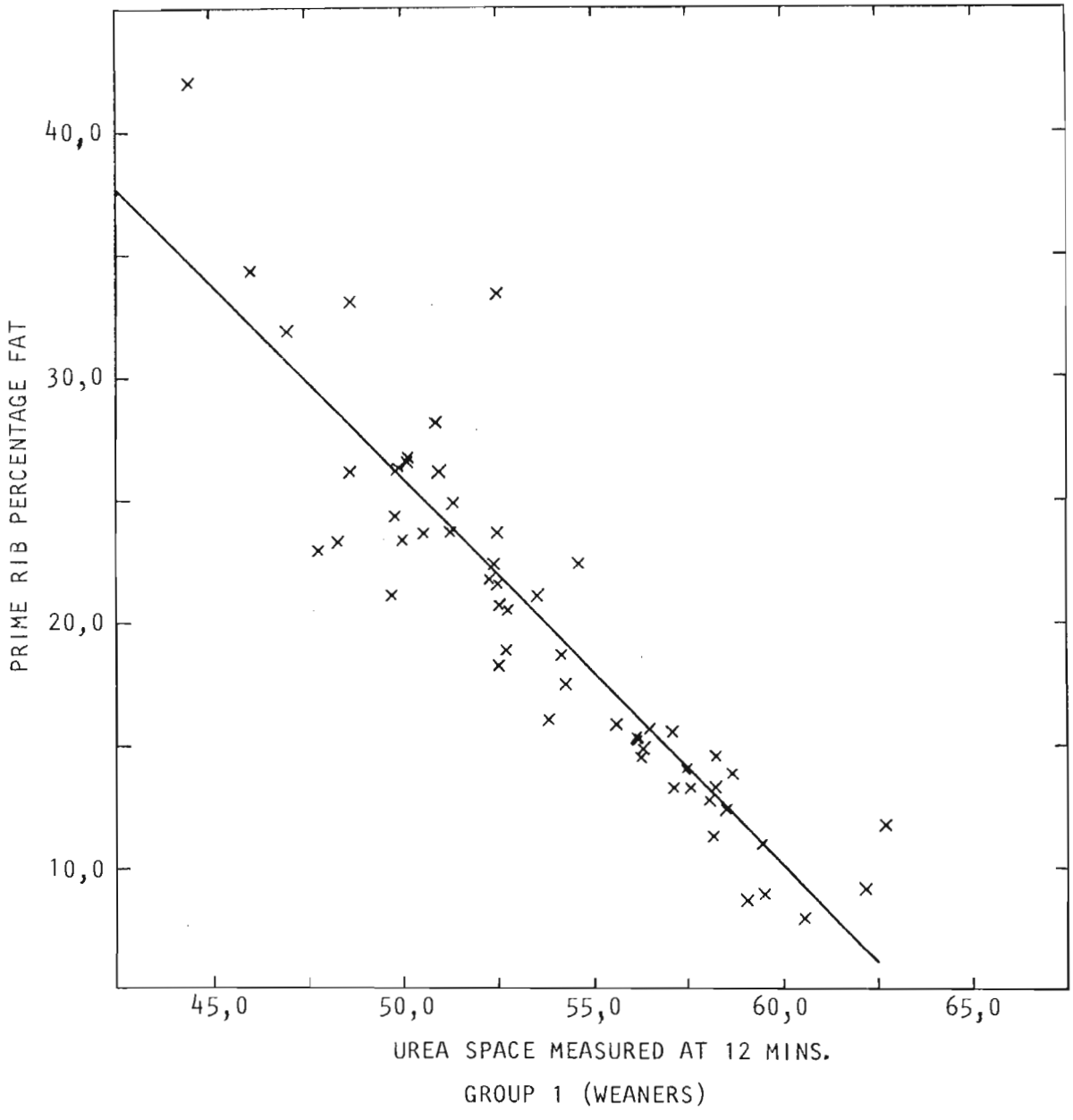

Fig. 4. Relationship between urea space (as a % of live mass at 12 minutes after urea infusion) and the percentage of fat in the prime rib for the weaner group.

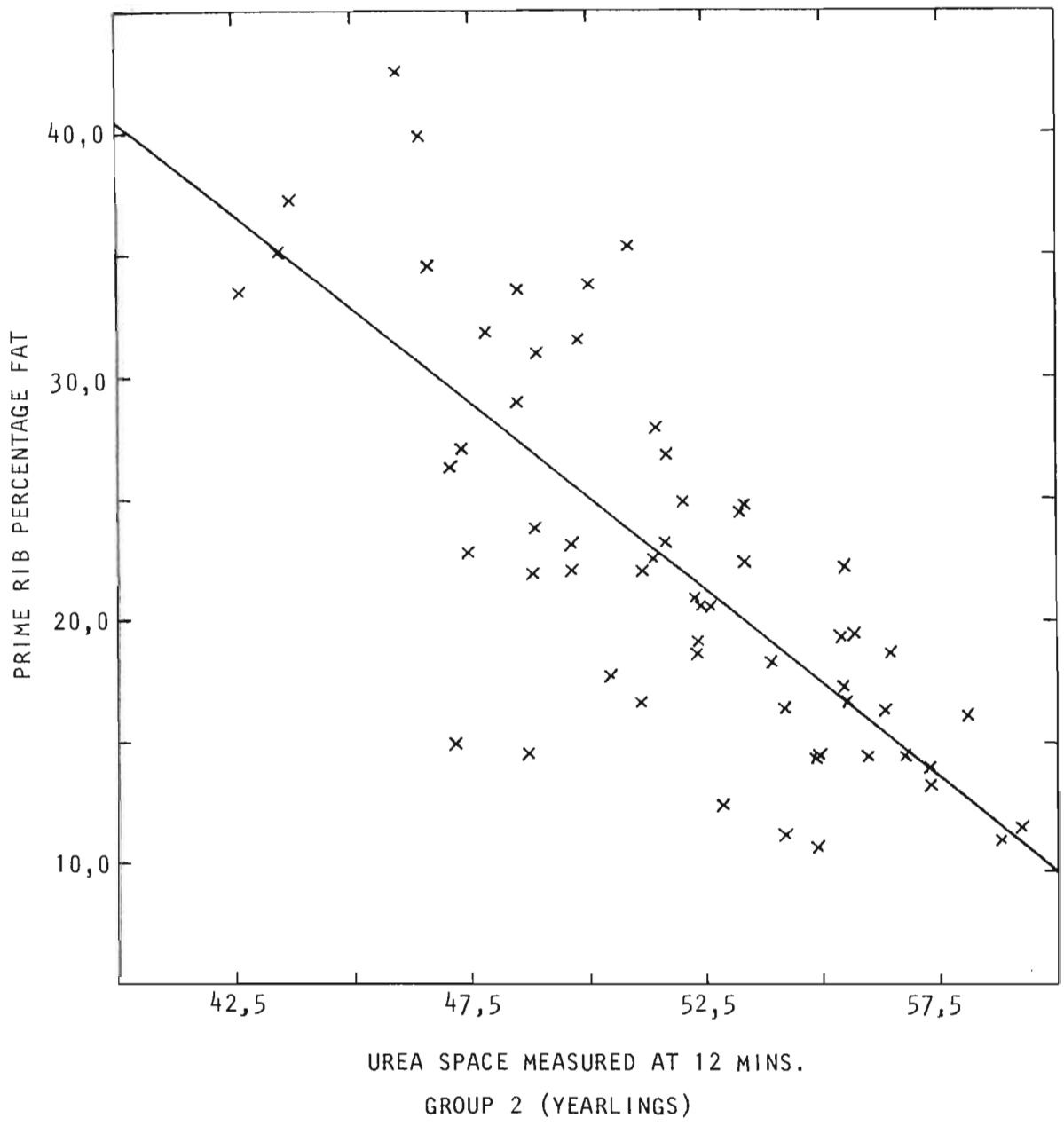

Fig. 5. Relationship between urea space (as a % of live mass at 12 minutes after urea infusion) and the percentage of fat in the prime rib for the yearling group.

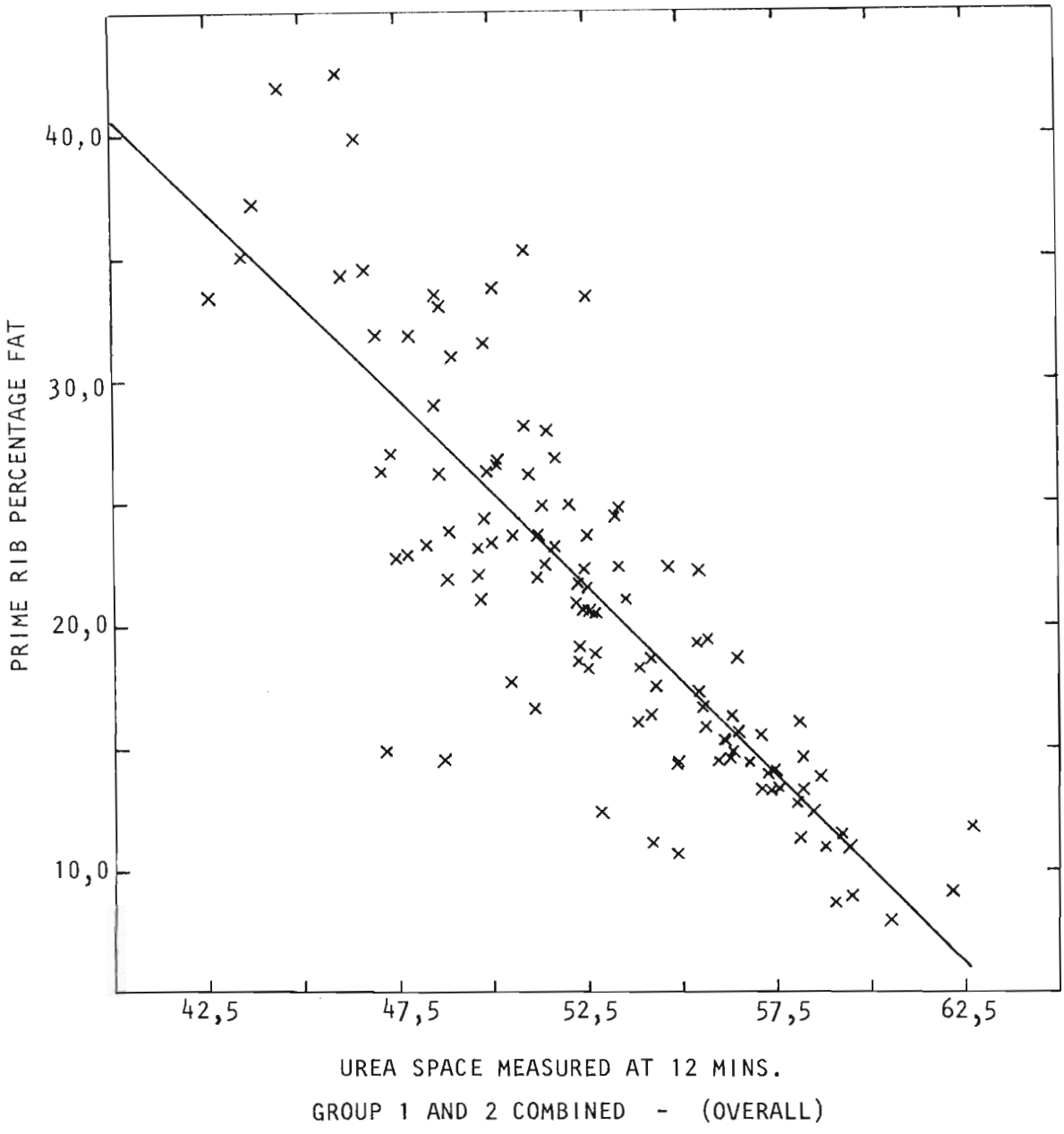

Fig. 6. Relationship between urea space (as a % of live mass at 12 minutes after urea infusion) and the percentage of fat in the prime rib for the overall group.

The data in Table 2, as illustrated in Fig. 7, show that the percentage of ash in the prime rib is not very strongly correlated with urea space. As in the previous cases, the highest correlation values were also obtained 12 minutes after urea infusion.

Table 3. Correlations between urea space (as a % of live mass and for various times after urea infusion) and the carcass specific gravity of weaner and yearling cattle.

Time after urea infusion (min)	Weaners	Yearlings	Overall
6	0,73	0,55	0,53
9	0,74	0,62	0,60
12	0,77	0,71	0,68
15	0,73	0,68	0,65
18	0,69	0,66	0,63

The data presented in Table 3 and in Fig. 8 give the relationships between urea space and the carcass, rather than the prime rib. Again, the correlation coefficient between urea space and carcass specific gravity was highest when calculated from the 12-minute post-infusion data.

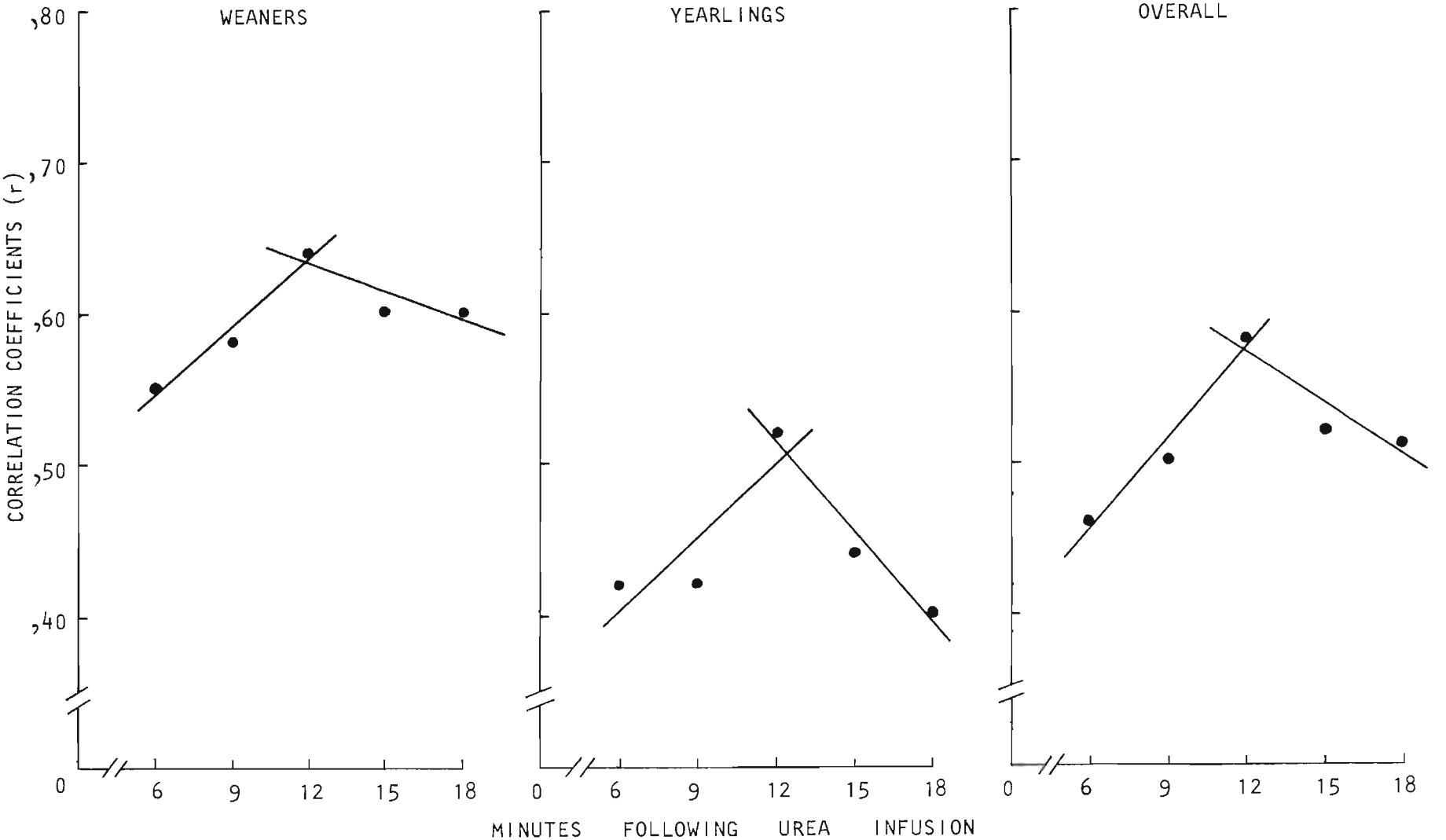

Fig. 7. Correlation coefficients between urea space (as a % of live mass, and for various times after urea infusion) and the percentage ash in the prime rib of weaner and yearling cattle.

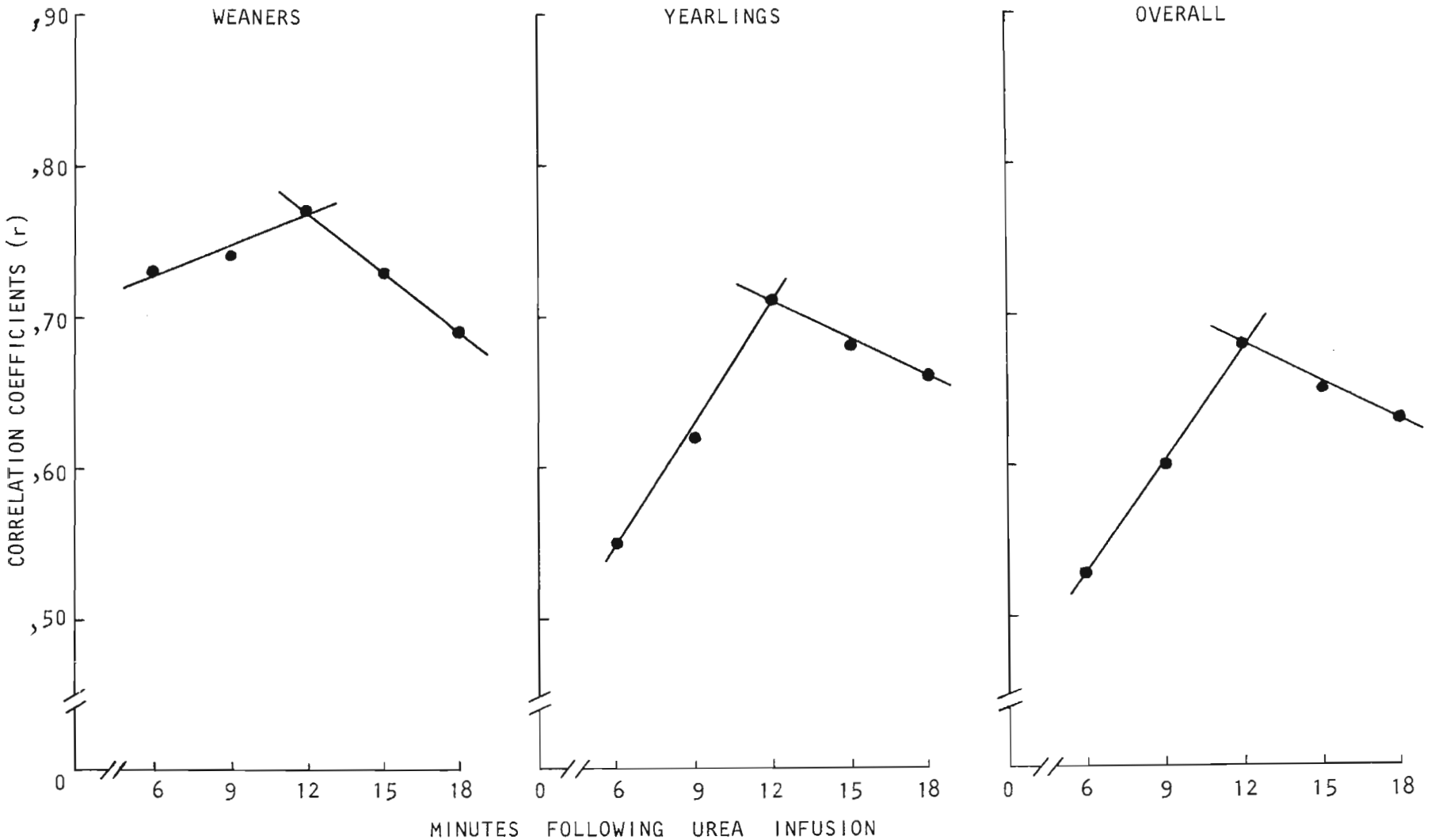

Fig. 8. Correlation coefficients between urea space (as a % of live mass, and for various times after urea infusion) and the carcass specific gravity of weaner and yearling cattle.

This holds for both weaners and yearlings. Although the numerical values of the correlation coefficients are not as high (0,77, 0,71 and 0,68 ,respectively, for the weaner, yearling and overall groups), the findings support the results obtained with the various prime rib constituents. Scatter diagrams (Figures 9, 10 and 11) are presented, showing the relationships between urea space and carcass specific gravity for weaner, yearling and overall groups, respectively.

The results presented up to this point reflect the analyses which were conducted on the data obtained when the animals were grouped according to age. The data were also analysed after regrouping the animals, first according to cold carcass mass and secondly by classifying the animals according to the fat content of the prime rib.

(b) Effect of cold carcass mass

The mean cold carcass mass for all the carcasses in the experiment was 201,5 kg. A total of 61 carcasses were below and 52 were above the mean cold carcass mass. The cold carcass mass of these two groups averaged 163 kg and 246 kg, respectively (Table 4).

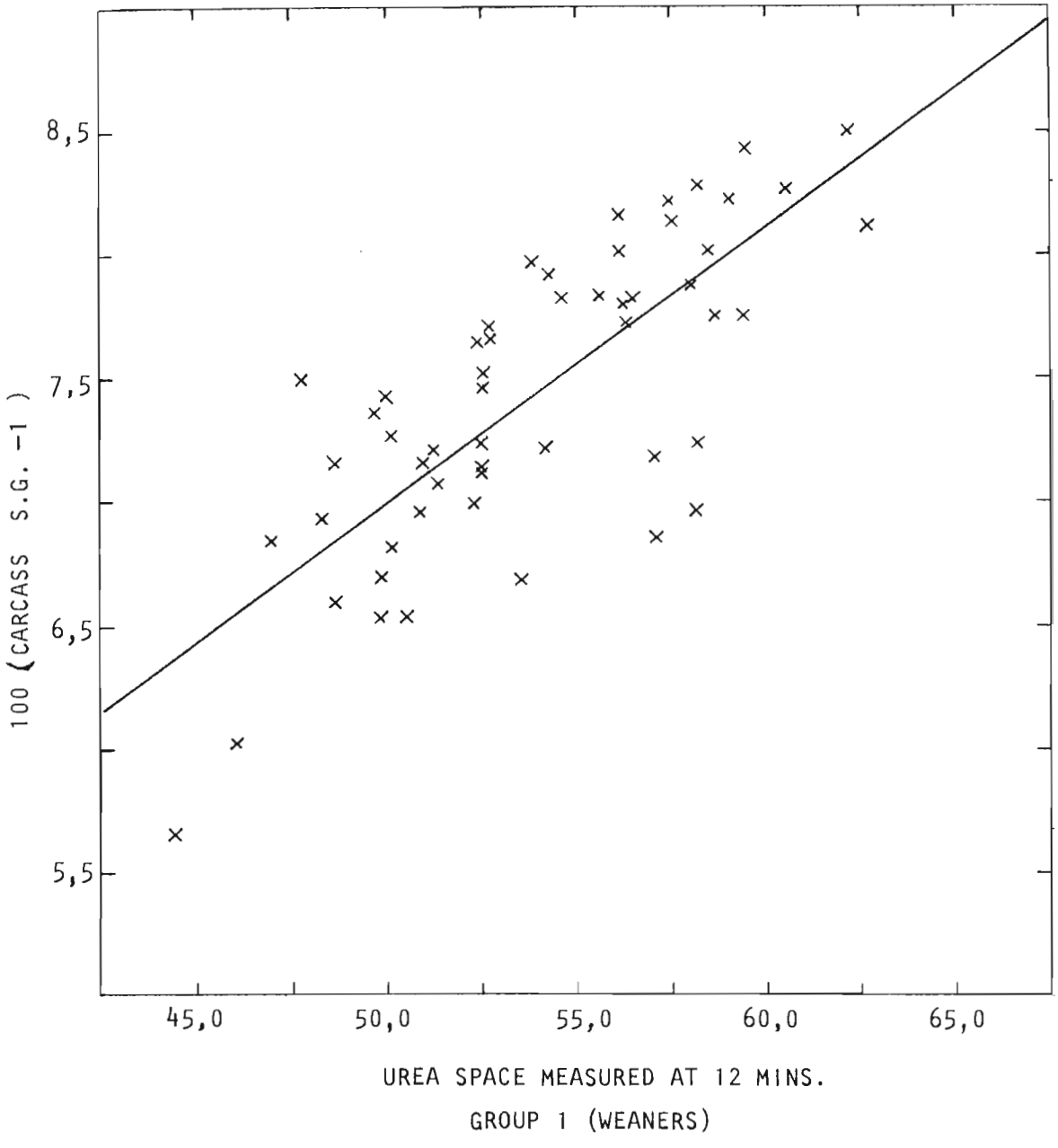

Fig. 9. Relationship between urea space (as a % of live mass at 12 minutes following urea infusion) and carcass specific gravity for the weaner group.

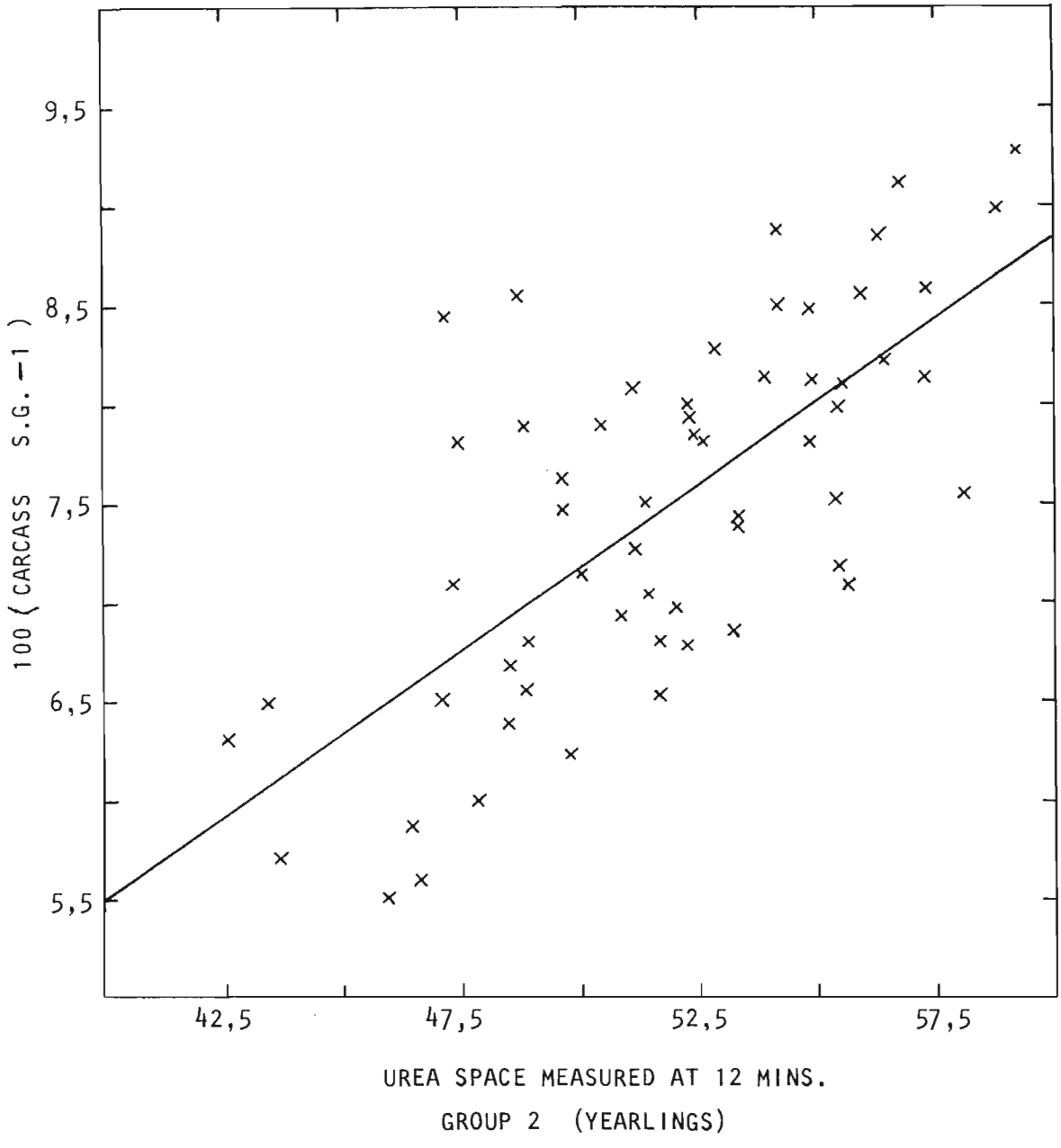

Fig. 10. Relationship between urea space (as a % of live mass at 12 minutes following urea infusion) and carcass specific gravity for the yearling group.

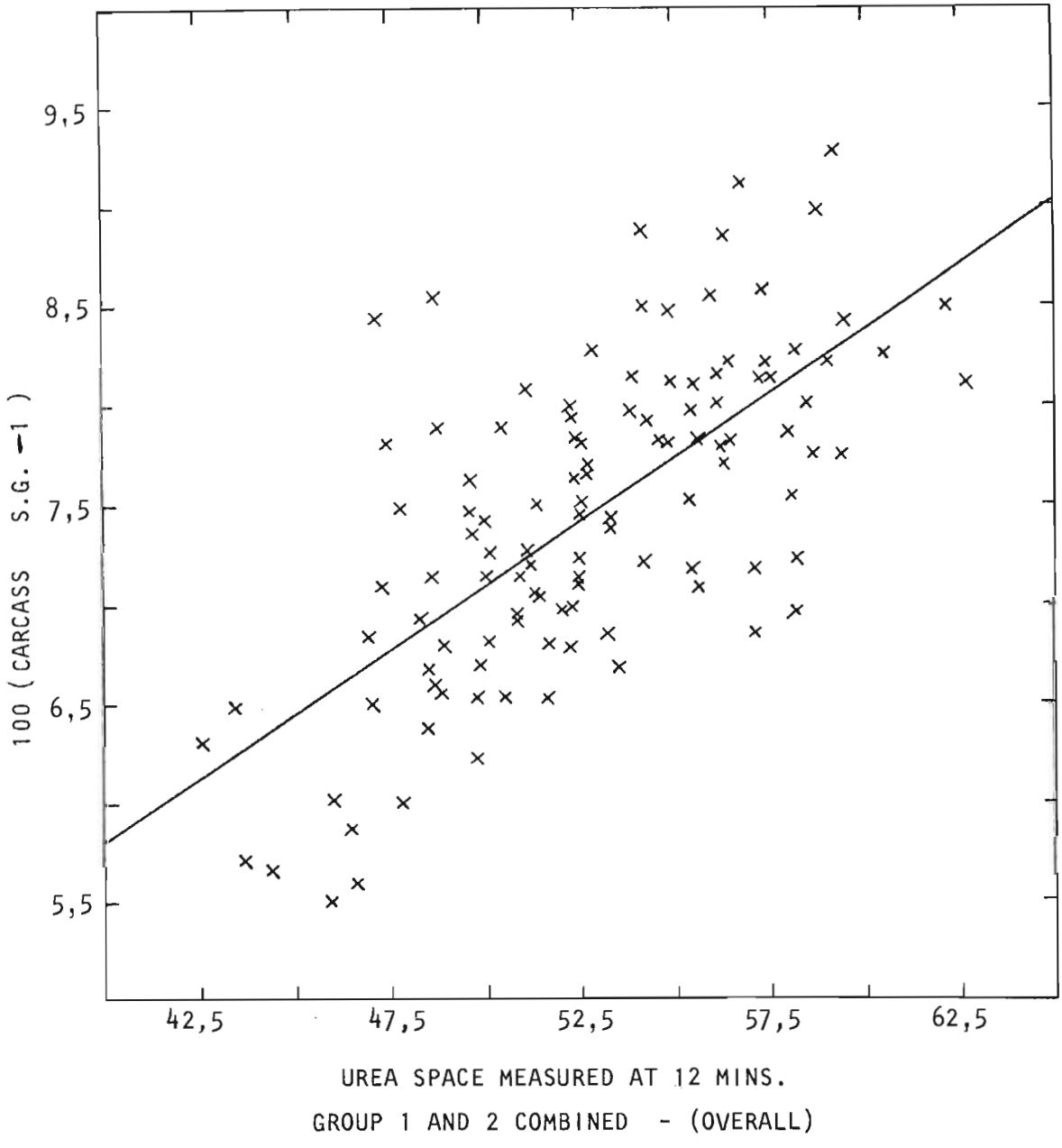

Fig. 11. Relationship between urea space (as a % of live mass at 12 minutes following urea infusion) and carcass specific gravity for the overall group.

Table 4. Means of cold carcass mass and fat percentage of the prime rib in light and heavy carcasses, together with standard errors and ranges.

		Light	Heavy
No of carcasses		61	52
Cold carcass mass (kg) :	mean	163	246
	S.E.	3,12	5,57
	range	105,0 - 201,5	201,6 - 349,0
Prime rib fat (%) :	mean	16,9	26,1
	S.E.	0,67	0,98
	range	8,0 - 33,4	11,0 - 42,5

The mean percentage of fat in the prime rib of the 61 light carcasses was 16,9. In the classification by age, the weaner group had an average of 19,8 percent fat in the same meat cut. Similarly, the heavy group had a prime rib mean fat percentage of 26,1 whereas the percentage was 22,4 for the yearling group. Clearly, the classification by cold carcass mass brought about the transfer of older animals of poor finish into the light carcass group and young animals of good finish into the heavy carcass group.

The data contained in Table 5 show the highest correlation coefficient between urea space and prime rib fat percentage at 12 minutes following urea infusion for both light and heavy carcass groups. For the light carcass group this correlation

Table 5. Correlations between urea space (as a % of live mass and for various times after urea infusion) and fat percentage of the prime rib on a basis of age, cold carcass mass and fatness of cattle .

Time after urea infusion (min)	Age		Cold carcass mass		Fatness		Overall
	Weaners	Yearlings	Light	Heavy	Thin	Fat	
6	-0,83	-0,60	-0,51	-0,61	-0,55	-0,57	-0,71
9	-0,87	-0,67	-0,64	-0,74	-0,60	-0,65	-0,76
12	-0,91	-0,76	-0,71	-0,82	-0,67	-0,75	-0,84
15	-0,86	-0,71	-0,67	-0,76	-0,63	-0,70	-0,79
18	-0,81	-0,68	-0,61	-0,74	-0,60	-0,65	-0,75

Table 6. Correlations between urea space (as a % of live mass and for various times after infusion) and carcass specific gravity on a basis of age, cold carcass mass and fatness of cattle.

Time after urea infusion (min)	Age		Cold carcass mass		Fatness		Overall
	Weaners	Yearlings	Light	Heavy	Thin	Fat	
6	0,73	0,55	0,19	0,57	0,11	0,46	0,53
9	0,74	0,62	0,28	0,64	0,19	0,50	0,60
12	0,77	0,71	0,36	0,78	0,27	0,61	0,68
15	0,73	0,68	0,37	0,72	0,25	0,52	0,65
18	0,69	0,66	0,34	0,71	0,17	0,47	0,63

coefficient was -0,71 and for the heavy carcass group -0,82.

When urea space was correlated with carcass specific gravity the results presented in Table 6 clearly show a high correlation (r = 0,78) at 12 minutes after urea infusion, but only for the heavy carcass group. The correlation for the lighter carcass group (r = 0,36) is much less satisfactory.

(c) Effect of fat content of the prime rib

In view of the low correlation between urea space and carcass specific gravity (Table 6) with light carcasses grouped according to cold carcass mass, the animals were also divided into thin and fat cattle by using the overall mean of 21,5 percent fat in the prime rib cut as the dividing point.

Table 7. Means of cold carcass mass and fat percentage of the prime rib in thin and fat cattle, together with standard errors and ranges.

		Thin	Fat
No. of animals		60	53
Cold carcass mass (kg) :	mean	174	232
	S.E.	5,20	6,53
	range	105,0 - 288,0	150,0 - 349,0
Prime rib fat (%) :	mean	15,3	27,7
	S.E.	0,44	0,77
	range	8,0 - 21,1	21,5 - 42,5

Division of animals into thin and fat categories did not bring about a pronounced change, from grouping according to cold carcass mass, in the size of the groups, nor in their prime rib fat contents (See Table 4).

Table 7 shows that 60 animals were grouped as thin cattle with less than 21,5 percent fat in the prime rib with a mean fat value of 15,3 percent. The remaining 53 animals represent fat cattle with more than 21,5 percent fat in the prime rib with a mean fat value of 27,7 percent.

The results presented in Table 5 indicate that both thin and fat cattle show good correlations between urea space and prime rib fat percentage. Best results were obtained at 12 minutes after urea infusion, giving correlation coefficients of -0,67 for thin and -0,75 for fat cattle, respectively.

The relationship between urea space and carcass specific gravity was satisfactory for fat cattle, but not so for thin cattle. The low correlations for thin cattle supports previous findings obtained with the light carcass group (Table 6).

From Fig. 12 it is clear that urea space measurements calculated from plasma samples drawn 12 minutes after urea infusion show the highest correlation coefficient between urea space and prime rib fat percentage for types of animals regardless of whether the animals were grouped according to age, cold carcass mass or fatness.

Similarly, urea space measurements estimated from plasma samples taken 12 minutes after urea infusion are strongly correlated with carcass specific gravity estimates, at least for carcasses obtained from weaners, yearlings, fat cattle and also cattle giving heavy carcasses (Fig. 13). The correlation coefficients are numerically smaller for cattle with a light carcass mass and for thin cattle, but the 12 minute sampling time remains the most acceptable.

(ii) Definition of urea space at 12 min after infusion

From all the results presented to this point it is clear that urea space measurements show the highest correlation coefficients with percentage fat in the prime rib and carcass specific gravity measurements from plasma samples drawn 12 minutes after the mean urea infusion time. Therefore, estimates of urea space are best made from plasma samples taken at the

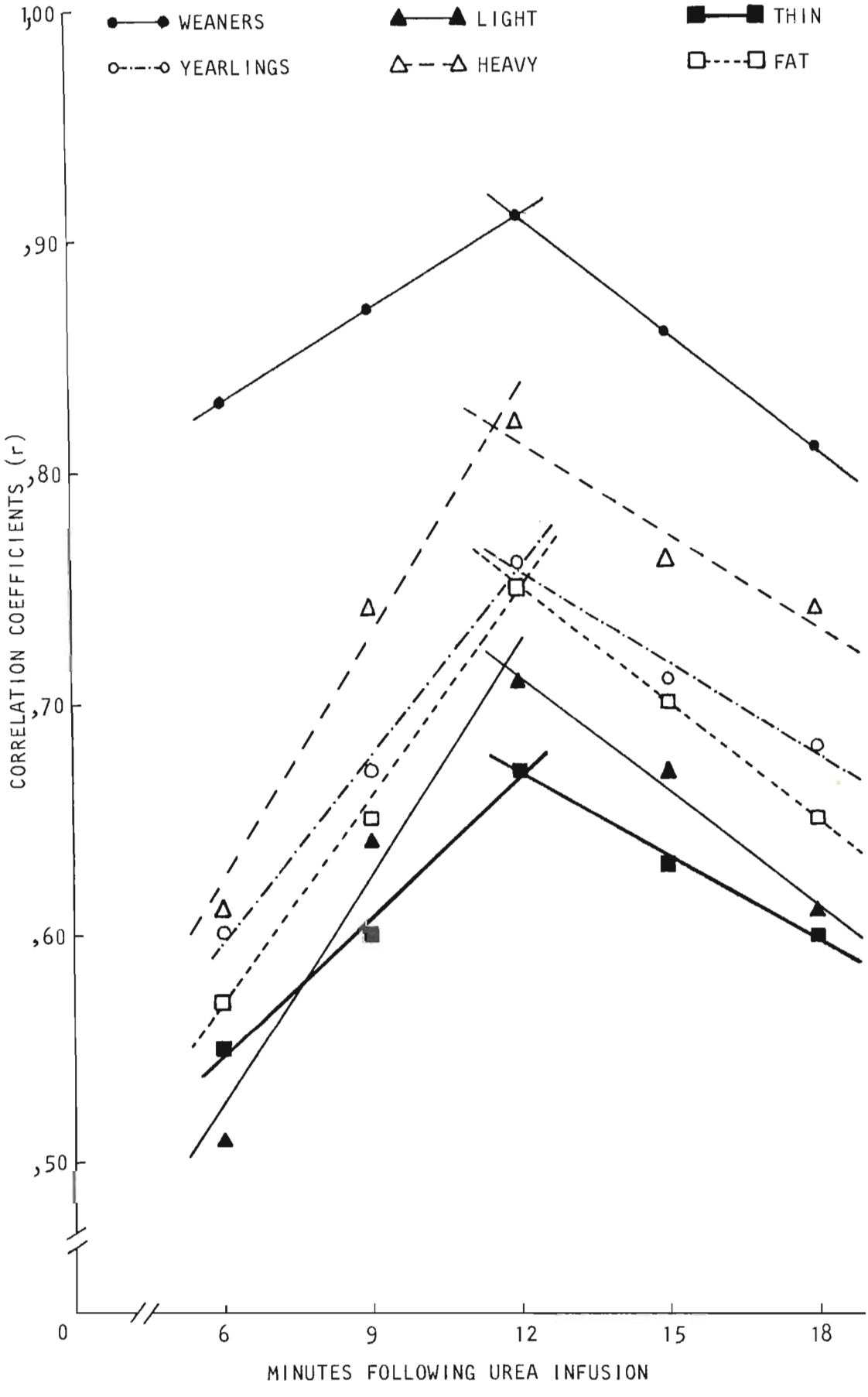

Fig. 12. Relationships between urea space (as a % of live mass and for various times after urea infusion) and fat percentage of the prime rib on a basis of age, cold carcass mass and fatness of cattle.

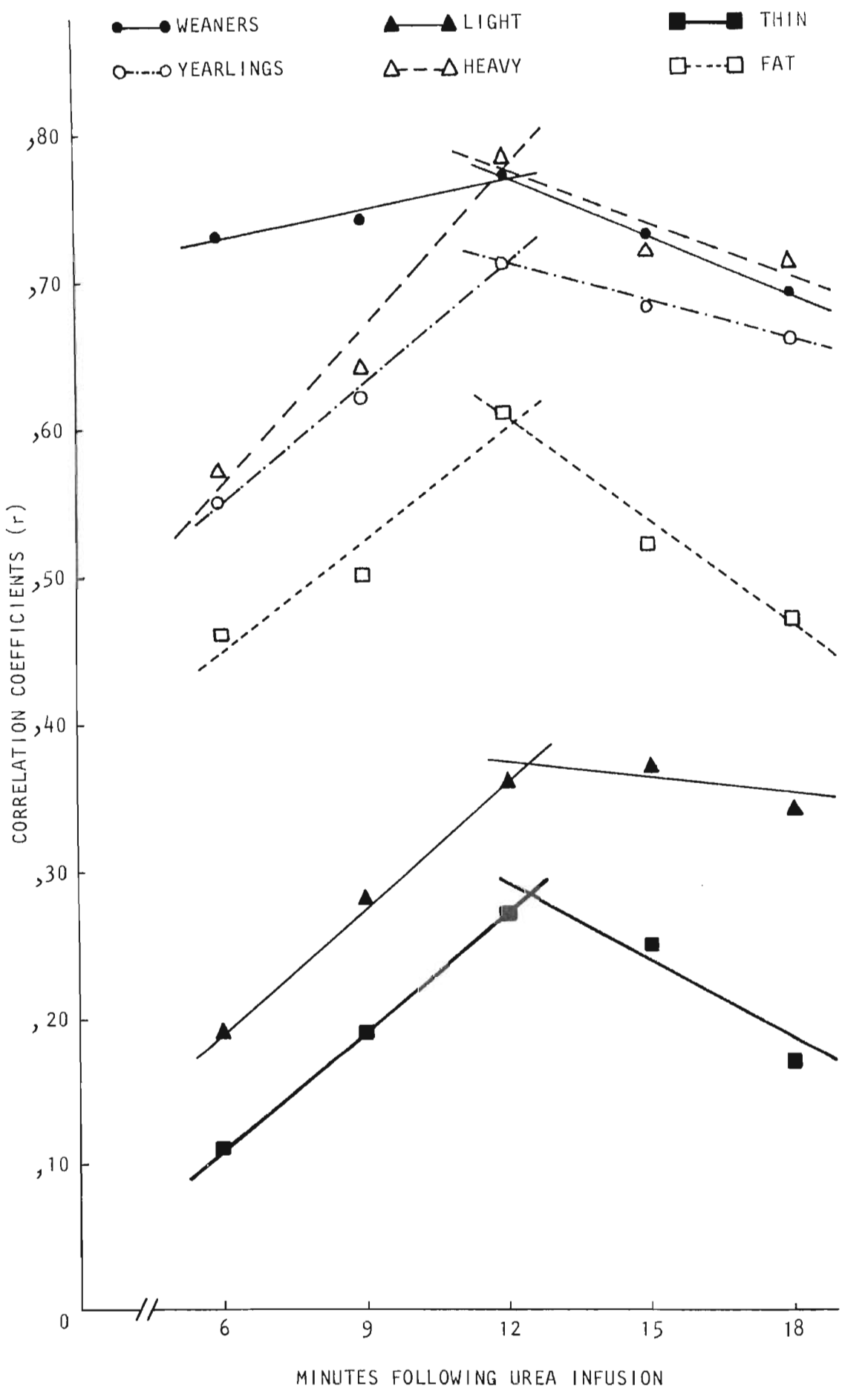

Fig. 13. Relationships between urea space (as a % of live mass and for various times after urea infusion) and carcass specific gravity on a basis of age, cold carcass mass and fatness of cattle.

12-minute post-infusion time. As a matter of convenience the abbreviation US-12 will be used henceforth to designate urea spaces determined from plasma samples taken at this time.

(iii) Relationship between the fat percentage of the prime rib and urea space

From the results obtained in this study the least squares regression line of percentage fat in the prime rib on urea space was computed from 113 animals as :-

$$\text{Prime rib fat \%} = 102{,}20 - 1{,}5368\ (\%\ \text{US-12}),$$
$$\text{with } r = -0{,}84$$

A multiple linear regression analysis was conducted to determine whether live mass would contribute to the precision of the regression equation for estimating the fat percentage of the prime rib. The least squares equation was

$$\text{Prime rib fat \%} = 78{,}39 + 0{,}0222\ (\text{live mass}) - 1{,}2373\ (\%\ \text{US-12})$$

and the multiple correlation coefficient - 0,85.

Since the correlation between urea space and prime rib percentage fat alone is -0,84 it is evident that the inclusion of live mass as a factor in the equation did not bring about any significant improvement.

(iv) Relationships between the constituents of the prime rib and carcass specific gravity

Correlations between prime rib composition and carcass specific gravity based on age, cold carcass mass and fatness of cattle are presented in Table 8.

It is evident from the results that light carcasses, and those classified as thin, generally show low correlations between carcass specific gravity and the constituents of the prime rib. Such correlations are higher for carcasses from yearlings, for heavy carcasses and for carcasses from fat cattle. The scatter diagrams (Figures 14, 15 and 16) show the relationships between the percentage of fat in the prime rib and carcass specific gravity for weaner, yearling and overall groups, respectively.

(v) Relationships between prime rib composition, carcass specific gravity and estimated carcass composition

The data recorded in Table 9 give the correlation coefficients between fat percentage in the prime rib, carcass specific gravity and urea space. The carcasses were divided into four groups on the basis of increasing cold carcass mass. The 28 lightest carcasses formed Group 1; the second 28 carcasses, slightly heavier, formed Group 2; Group 3 included the next 29 carcasses and the remaining 28 heaviest carcasses constituted Group 4. The mean fat percentage in the prime rib cuts were 14,5; 18,2; 24,5 and 27,3 for the four groups,

Table 8. Correlations between the constituents of the prime rib and carcass specific gravity on a basis of age, cold carcass mass and fatness of cattle.

Prime rib constituents	Age		Cold carcass mass		Fatness		Overall
	Weaners	Yearlings	Light	Heavy	Thin	Fat	
% water	0,80	0,90	0,63	0,87	0,45	0,87	0,84
% protein	0,64	0,80	0,54	0,74	0,34	0,57	0,75
% fat	-0,80	-0,90	-0,65	-0,87	-0,48	-0,87	-0,84
% ash	0,52	0,63	0,38	0,63	0,15	0,54	0,58

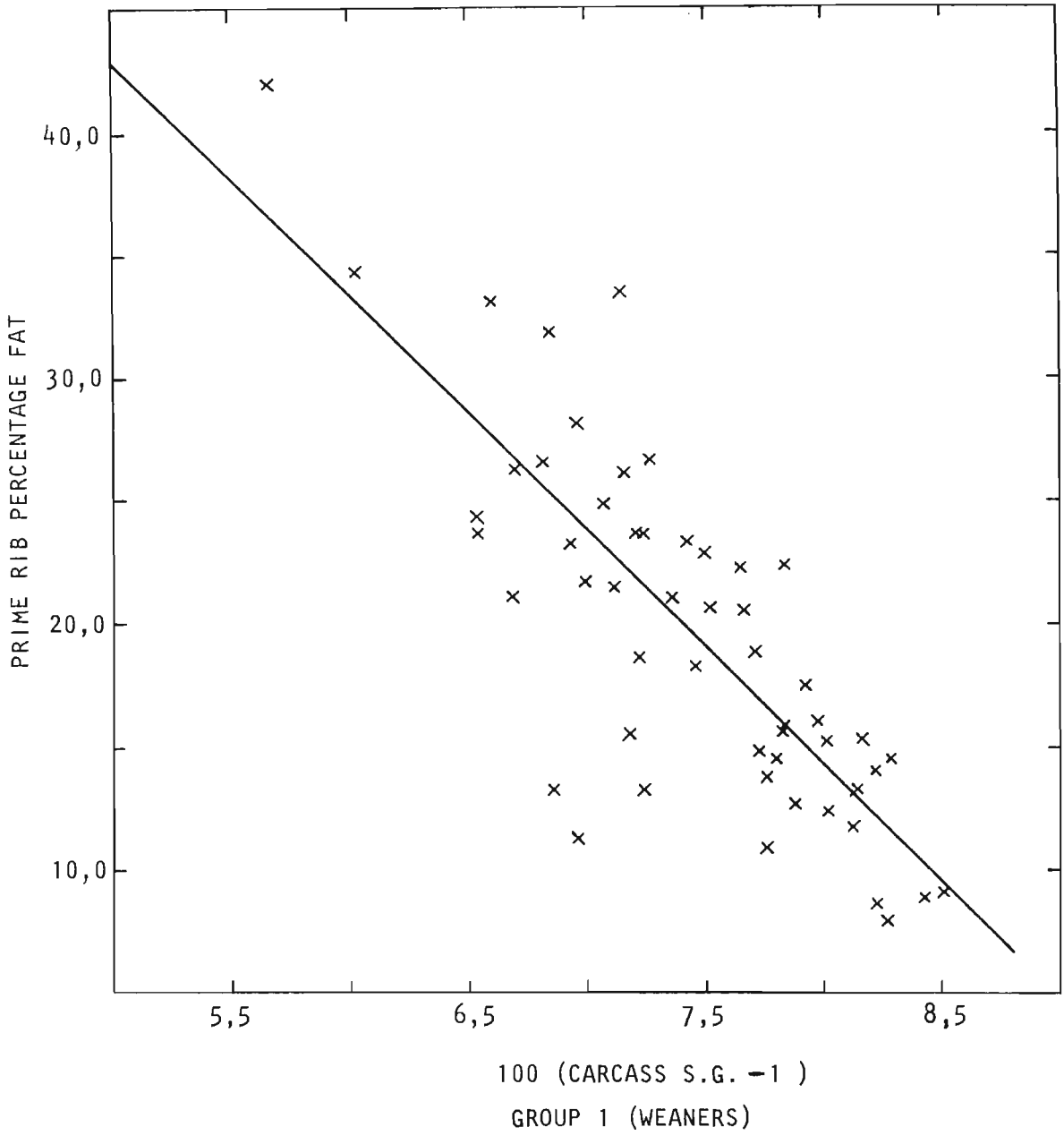

Fig. 14. Relationship between the percentage of fat in the prime rib and carcass specific gravity for the weaner group.

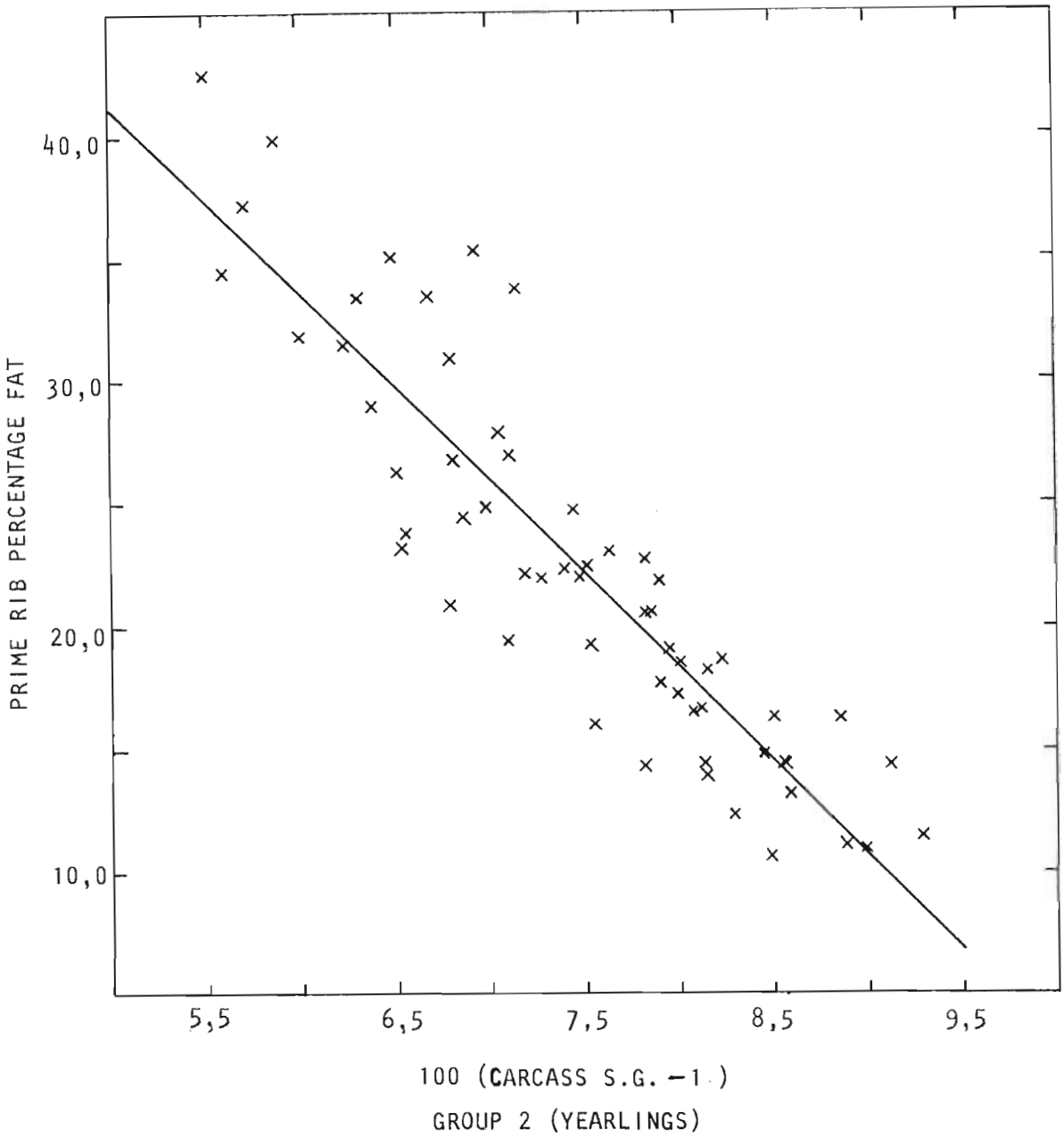

Fig. 15. Relationship between the percentage of fat in the prime rib and carcass specific gravity for the yearling group.

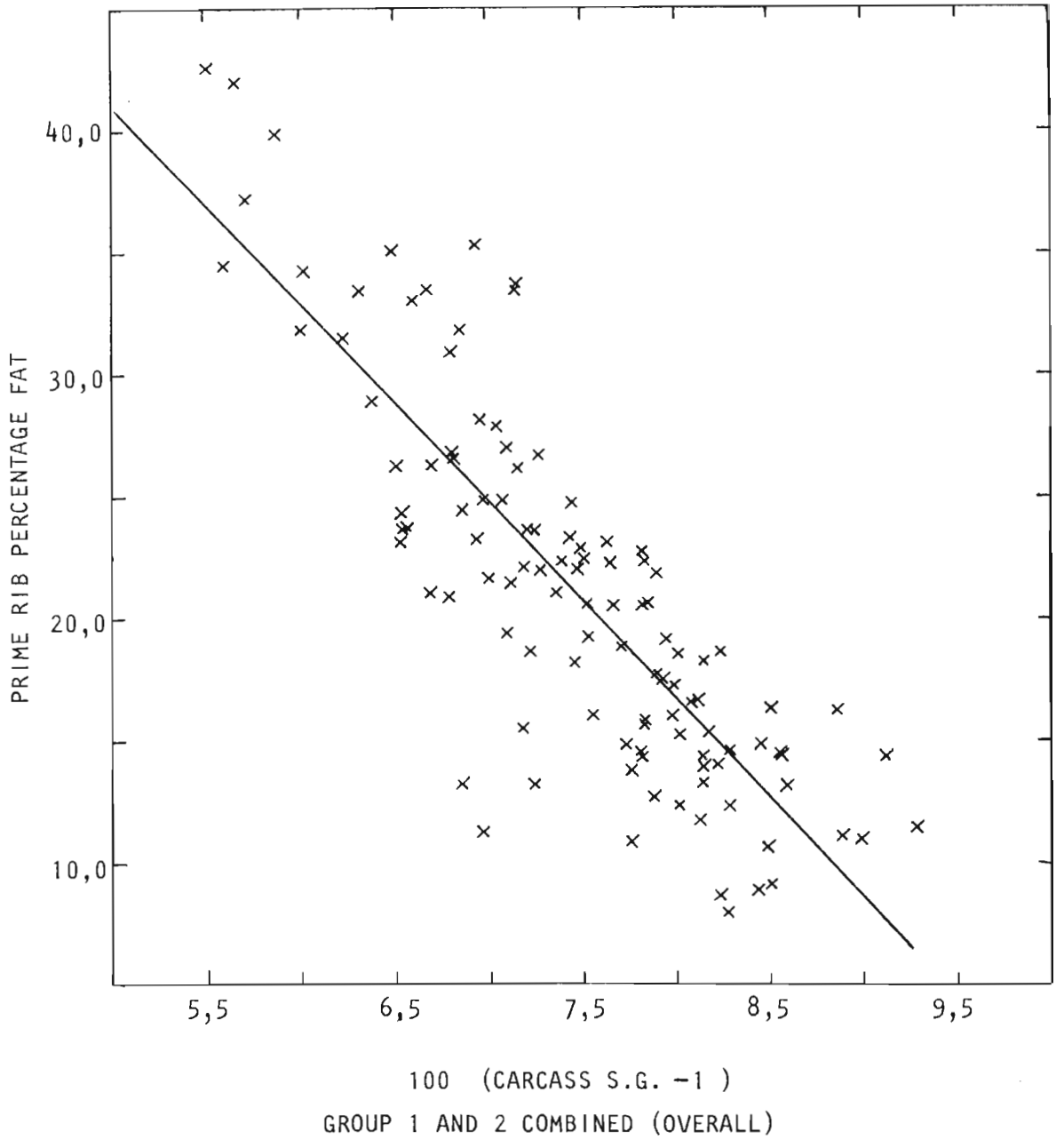

Fig. 16. Relationship between the percentage of fat in the prime rib and carcass specific gravity for the overall group.

Table 9. Correlation coefficients between percentage fat in the prime rib, carcass specific gravity and urea space in four groups of animals.

Variable	Group 1 n[a] = 28 PRF[b] = 14,5 CSG[c] = 1,07881	Group 2 n = 28 PRF = 18,2 CSG = 1,07749	Group 3 n = 29 PRF = 24,5 CSG = 1,07233	Group 4 n = 28 PRF = 27,3 CSG = 1,06953
PRF vs US -12[d]	-0,80	-0,79	-0,77	-0,81
CSG vs US-12	0,24	0,69	0,84	0,74
PRF vs CSG	-0,44	-0,79	-0,79	-0,90

a. n = number of carcasses

b. PRF = mean fat percentage in the prime rib

c. CSG = mean carcass specific gravity

d. US-12 = urea space at 12 min after urea infusion

respectively (Table 9).

In comparing prime rib composition and carcass specific gravity as a predictor for carcass composition, only the percentage fat in the prime rib was used in this particular analysis.

It appears from the results presented in Table 9 that :

(a) the relationships between percentage fat in the prime rib and US-12 were strongly correlated for all groups, i.e. r values of -0,80; -0,79; -0,77 and -0,81, respectively;

(b) the relationships between carcass specific gravity and US-12 were high for Groups 2, 3 and 4 with r values of 0,69; 0,84; and 0,74, respectively;

(c) the percentage fat in the prime rib was strongly correlated with carcass specific gravity for Groups 2 - 4 inclusive. The respective r values were -0,79; -0,79 and -0,90;

(d) group 1, i.e., light carcass group with a mean prime rib fat content of approximately 14 - 15 percent shows only low correlations between carcass specific gravity and US-12 (r = 0,24) and between carcass specific gravity and percent fat in the prime rib (r = -0,44).

(vi) Relationships between the components of the cut

The results in Table 10 indicate the relationships between the various chemical constituents of the prime rib for weaner and yearling cattle. The overall correlations between the percentage of water in the prime rib and its content of protein or of fat were high, but the correlation between water content and ash content in this carcass cut was not as high. In general, these relationships were somewhat stronger for the yearling than for the weaner group of cattle (Table 10).

Table 10. Correlations between chemical constituents in the prime rib of weaner and yearling cattle.

Variable		Weaners	Yearlings	Overall
X	Y			
% water	% protein	0,82	0,93	0,87
% water	% ash	0,71	0,67	0,69
% fat	% water	-0,997	-0,998	-0,997
% fat	% protein	-0,86	-0,94	-0,90

GENERAL DISCUSSION

Much effort is put into the planning of any research project and this certainly is also true in the field of body composition. Body composition studies are required as a useful means to improve our livestock for human consumption. However, in the past, not enough emphasis was placed on the use of body composition as a measure of response to nutritional or genetic manipulations.

The livemass change of cattle has been used extensively in both nutritional and genetic studies of animal performance. This measure does not, however, provide sufficient information relative to the changes in body composition which were experienced by the animals being tested. Similarly, the use of carcass mass as a measure of response has its limitations. Neither live mass nor carcass mass can give any indication of carcass quality. While a system of grading aimed at separating carcasses into quality categories can serve a useful purpose, it is not an experimentally useful approach since the grade awarded may be influenced by the grader himself or by other variables like conformation, age, fat distribution or bruising of the carcass. For these reasons it would be very desirable if assessments of carcass quality could be obtained by more repeatable and more reliable objective measurements.

A considerable number of studies on live animals and on their carcasses have been reported in the literature. Much progress

has also been made in developing various methods for estimating the body composition of the living animal. Some of the methods developed for this purpose have already been indicated.

The percentage composition of the animal carcass is relatively constant for water (± 74%), protein (± 21%) and ash (± 5%) provided the fat content has been excluded (Reid et al. 1955; Preston et al. 1974). Carcass fat may be regarded as a diluent for the remaining components in the carcass and, therefore, the variation in the carcass composition of cattle is almost entirely due to the variation in their fat content. Since the fat-free body contains water in a fixed proportion and assuming that accurate measurements of body water can be made in the live animal, it follows that the other body components can be estimated with reasonable accuracy from the body water content. In other words, if the percentage of water in the body can be determined, the percentage of protein and ash can be estimated. The difference between 100 and the total percentage of water, protein and ash is the percentage of fat in the animal.

Using a marker, it would be possible to determine the percentage of water in the live animal by determining the dilution of this marker in the water of the animal's body. In this study urea was used as a marker to determine urea space. Urea space may be defined as the volume of water into which urea is dispersed. If it is assumed that urea space is related to empty body water, then urea space measurements may offer a means of predicting body composition in cattle.

In determining urea space measurements, live mass plays an important role. In the research reported here, the volume of urea to be infused into the animal was accurately calculated from the fasted live mass (130 mg Urea/kg live mass). It has been reported that the gastro-intestinal fill in ruminants can contribute 5 to 30% error to the live mass measurement depending on the condition of the animals at slaughter and on the pre-slaughter treatments such as length of fasting (Reid et al. 1963; Bensadoun et al. 1968). Such error may be reduced by withdrawing food and water for a period of time prior to weighing. In this investigation the animals were deprived of food and water from the previous afternoon (approximately 16h00) until the next morning, after which the animals were weighed, urea was infused and blood samples were taken for subsequent analysis.

Preston and Kock (1973) comment that in view of the known influence of gastro-intestinal fill, it is not surprising that percentage empty body fat was more strongly correlated with urea space expressed as a percentage of live mass. Empty body mass is difficult to obtain under practical abattoir conditions and for this reason live mass has been used as the basis for expressing urea space measurements in all the calculations in the present study.

Preston and Kock (1973) reported that sampling of blood 12 to 15 minutes after urea infusion gave the best relationships

between urea space measurements and percentage empty body fat and percentage empty body water in cattle. In the present study, when urea space was correlated with either fat percentage in the prime rib or with carcass specific gravity, the highest correlation coefficients were obtained from the urea space data based on the 12 minutes post-infusion sampling time (US-12).

The illustration presented in Fig 17 indicates various "correlation pathways" between some of the compositional parameters. The results from the present investigation show the following relationships:

(i) a correlation coefficient (r) of -0,84 between US-12 and the percentage of fat in the prime rib;

(ii) a correlation coefficient (r) of 0,68 between US-12 and carcass specific gravity;

(iii) a correlation coefficient (r) of -0,84 between the percentage fat in the prime rib and carcass specific gravity.

Findings of other research workers include the following:

(iv) Correlation coefficient (r) of 0,88 between percentage urea space (% of live mass) measured at 12 minutes after urea infusion and carcass specific gravity (Preston and Kock, 1973);

(v) correlation coefficient (r) of -0,95 between percentage

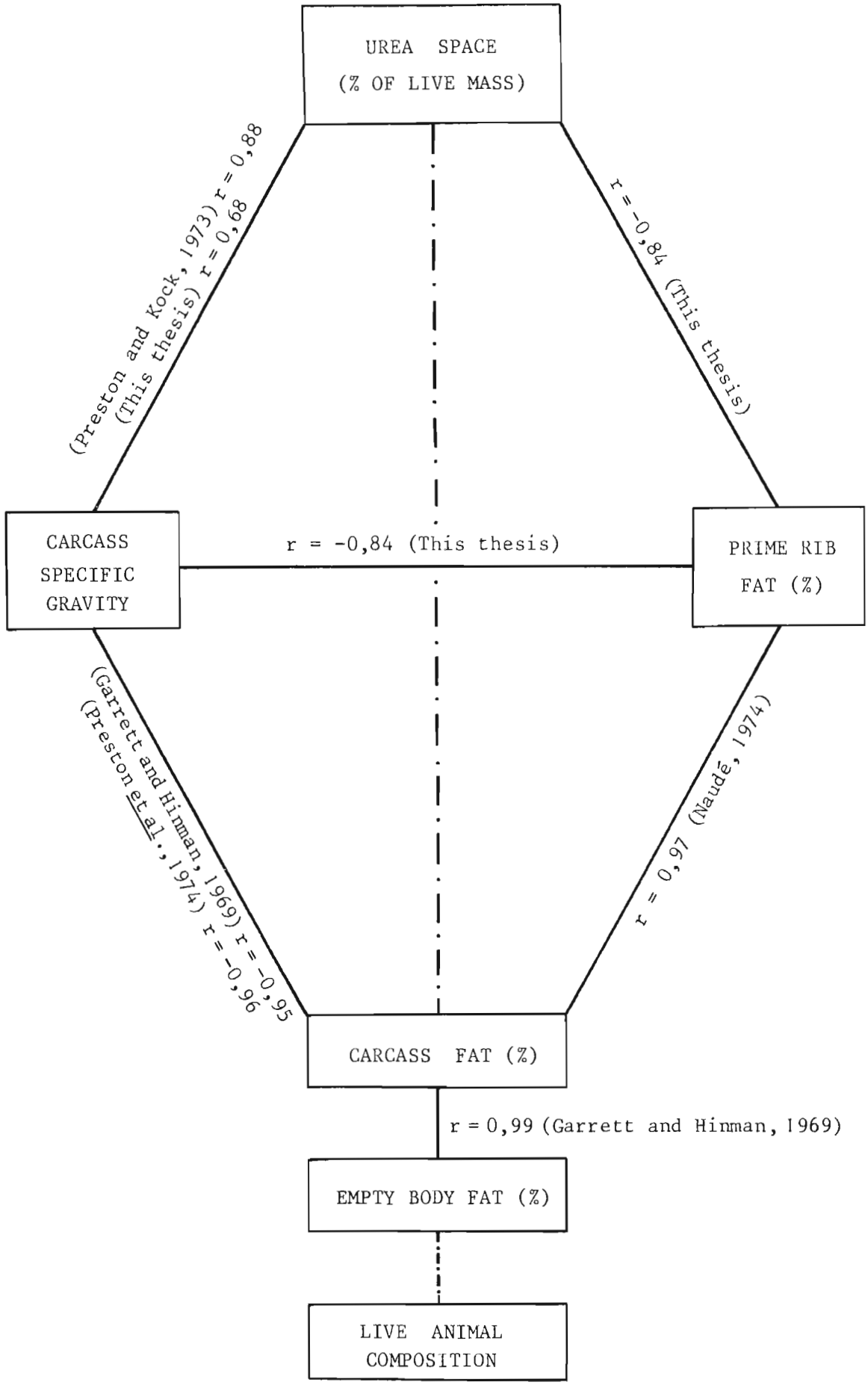

Fig. 17. "Correlation pathways" from urea space to live animal composition.

ether extract from the carcass and carcass density (Garrett and Hinman, 1969);

(vi) correlation coefficient (r) of -0,96 between carcass fat composition and carcass specific gravity (Preston et al., 1974);

(vii) correlation coefficient (r) of 0,97 between percentage fat in the prime rib cut and percentage fat in the carcass (Naudé, 1974);

(viii) correlation coefficient (r) of 0,99 between carcass fat and empty body fat (Garrett and Hinman, 1969).

It may be argued that animals of different types and origin were used to obtain these various relationships and that it would be questionable to use such correlations for estimating the composition of the living animal, beginning with urea space measurements. According to Rayner (1967) : "Great caution must be exercised, however, before a significant correlation is interpreted as indicative of direct cause and effect, even when there is only one possible direction of influence. Other variates, not even taken into consideration, may be affecting the relationship of the variates under observation. A correlation is frequently brought about partly or even wholly by the fact that the two variates are each correlated with a third variate. Thus it seems fairly obvious that, if x_1 and x_2 are both positively correlated with x_3, then x_1 and x_2 will be positively correlated.

It would then be desired to examine the correlation between x_1 and x_2 when allowance is made for correlations with x_3, i.e., on the assumption that x_3 is kept constant". He continues by saying that such partial correlation coefficients may be valuable in clarifying the evidence, but that they do not provide more proof of the existence of causal relationships than an ordinary correlation coefficient.

Studies which use only correlations may also be criticised on the grounds that the correlation coefficient is a measure of linear dependence whereas the relationships between two variables which may well be linear over a restricted range of observations may actually be curvilinear over an extended range. The data reported in this study cover a wide range of animals (between 150 and 445 kg live mass) and still give good linear relationships between US-12 and percentage fat in the prime rib and carcass specific gravity measurements, respectively. Within the same range of live mass similar linear relationships between percentage fat in the prime rib and carcass specific gravity were also obtained in this investigation.

The urea dilution technique for estimating body composition in vivo may offer certain advantages over the present methods being used to measure body composition. In order to obtain body composition data at any stage during the experimental period the most conventional and practical method being used is to slaughter the animals at different stages. This, for obvious

reasons, requires a larger number of animals for the experiment. If the animals were not slaughtered, the individual growth pattern of each animal in respect of their bone, muscle and fat ratios throughout the experimental period could also be studied. The urea space method provides an inexpensive, simple and reasonably accurate means of assessing body composition in live cattle and yet has no adverse effect on the carcass. Therefore, it may be useful in performance testing trials or it may assist feedlot managers to assess the degree of finish of their stock. In large feedlot groups, if of uniform type, the method could also be used by applying it to a random sample of the group. Cattle breeders would find accurate live animal evaluation of great advantage in developing animals with good genetic and metabolic characteristics.

This study compared urea space measurements with either prime rib cut analyses or carcass specific gravity measurements rather than whole carcass analyses. Unfortunately the last was not possible in this investigation and further studies should be aimed in this direction.

The urea space technique requires more research aimed at refining the method for greater precision in assessing live animal composition. In order to obtain accurate results, care must be taken to weigh the animals accurately, since the volume of urea to be infused into the animal is calculated from the fasted live mass. The animal must be properly restrained

during catheterization, urea infusion and blood sampling. To accomplish this effectively good handling facilities, such as a body and neck clamp as well as a halter, are required, and every effort should be made to minimise stressful influences prior to and during the procedure.

Details of the methods used, both for the infusion technique and the analysis of the plasma have been described and summaries of these methods are presented in Appendices 1 and 2, respectively.

Several workers have reported that carcass specific gravity has low predictive values for estimating body composition of thin cattle (Kelly et al. 1968; Waldman et al. 1969; Gil et al. 1970). Gil et al. (1970), using animals of varying degrees of fatness, found significant correlations between specific volume and percent water, protein and fat in quarter carcasses, but only in those from fat cattle (30 to 42% fat). The correlations between specific volume and percent ash, however, were significant for all carcasses, except those from lean carcasses (10 to 15% fat), suggesting that carcass density was more associated with bone growth than with other tissues, particularly in the younger animals. When all (59) quarter carcasses were analysed in one regression, significant coefficients of determination were obtained between specific volume and percent water, protein, fat and ash with R^2 values of 0,74, 0,74, 0,79 and 0,65, respectively. Preston et al. (1974) investigated the effect of bone proportionality

on the relationship between carcass specific gravity and carcass composition. Bone proportionality in cattle within the range of 11,7 to 18,6% separable bone was found not to change the relationship between carcass specific gravity and carcass composition. However, it was noted that bone proportionality might still affect these relationships in cattle with a wider range of fatness from 16,6% to 38,6%.

From the data obtained in the present study the percentage fat in the prime rib showed better relationships with carcass specific gravity measurements of the carcasses derived from the heavier or fatter rather than from the lighter or thinner cattle (Table 9). Heavier cattle included those whose carcasses had a mean prime rib fat content of 18% or more, and light cattle yielded carcasses with a mean prime rib fat content of approximately 14 - 15%. The analysis of the data presented in this study again emphasise that light carcasses with a low degree of fatness, approximately 14 - 15% fat in the prime rib cut, do not give very reliable results with the specific gravity technique. Both techniques, the composition of the prime rib cut and the carcass specific gravity method are suitable for estimating carcass fat content in cattle of at least reasonable finish, but the specific gravity technique is not very accurate when carcasses contain less than 14-15% fat in the prime rib cut.

A new system for the sale of carcasses by catalogue has recently

been introduced at one of the largest abattoirs in South Africa. The sale takes place in the absence of the carcasses and buyers are provided with information, suitably coded, on items such as sex, conformation, finish, colour of fat, amount of internal fat, damage and trimming, age, grade and carcass mass. Most of these items are subjective in character, making it difficult for the potential buyer to bid for a specific type of carcass. More objective methods such as carcass specific gravity would provide valuable additional information in the overall assessment of the carcasses offered for sale, and would permit purchasers greater precision in acquiring carcasses of the desired degree of fatness.

SUMMARY

The main purpose of the investigation reported in this dissertation was to establish a reliable and useful estimate of body composition of the live animal. Live animal evaluation will provide researchers with a basis for establishing the body composition of the living animal on a continuing basis as the animal passes through its various stages of development, and this without adversely affecting the animal or the product. If the composition of live cattle is known at specific stages of their growth, faster progress can be made in identifying genetic lines of cattle which contain more lean meat and less fat. Such a predictor of body composition of the live animal may indirectly also assist producers in making sound breeding, feeding and selection decisions.

Various methods for estimating the body composition of the live animal have been developed and will continue to receive much attention from researchers in the future. Such methods include the use of subjective visual appraisal, live animal measurements, ultrasonic probes, dilution techniques, potassium - 40 and others. Each of these methods has given satisfactory results under particular conditions, yet each suffers from its own distinct disadvantages. Some of the limitations include operating cost and time, accuracy and reliability of the method and the usefulness of applying such a technique under practical conditions.

In this study urea was used as a marker to determine the dilution of the chemical in the water of the animal's body. Urea space may be defined as the volume of water with which urea equilibrates. If it is assumed that urea space is related to empty body water, then urea space measurements may be used as a predictor for estimating body composition in cattle.

One hundred and fifteen animals of a cross between British Breed types and Dual Purpose Breed types were used in this investigation. The animals represented two age groups. The first group consisted of 56 weaner calves with live mass ranging between 150 - 270 kg (mean 210 kg). The second group comprised 59 older animals, approximately 20 months of age, with live masses ranging from 220 - 445 kg (mean 330 kg). The animals from each group were randomly allotted to smaller sub-groups of eight animals each, for slaughter at various predetermined stages throughout the trial.

Urea space was determined on each animal prior to slaughter. This involved the intravenous infusion of a known concentration of a urea solution. The volume of urea to be infused into the animal was accurately calculated to provide 130 mg Urea/kg fasted live mass. Blood samples were taken through a catheter prior to infusion and at six, nine, 12, 15 and 18 minutes post-infusion. The blood plasma was analysed subsequently for its urea nitrogen content. Urea space was calculated and expressed

as a percentage of the fasted live mass. This procedure was carried out to establish the optimum time at which to measure urea spaces after infusion. As a matter of convenience the abbreviations US-6, US-9, US-12 etc. may be used to designate urea spaces determined from plasma samples taken at 6 min, 9 min, 12 min etc. after the mean urea infusion time.

Many workers have taken carcass measurements and examined their usefulness in predicting carcass composition. Such measurements included carcass mass, backfat thickness, area of m. longissimus dorsi (rib-eye area), carcass length, carcass depth, carcass width and many more. Such measurements have generally only limited usefulness in the evaluation of carcasses. Even subjective grading of carcasses, the traditional method being used in many countries, has its disadvantages since the grade awarded may be influenced by the grader himself or by other factors such as conformation, age, fat distribution or bruising of the carcass. For these reasons assessment of the carcass by more reliable objective measurements such as carcass specific gravity and the composition of the prime rib cut (8-9-10th rib) was also investigated. The relationship between urea space and these two measurements was also examined.

Urea space values for each sampling time were correlated with the percentages of water, protein, fat and ash obtained from the prime rib cuts. The correlation coefficient between

urea space and the percentage of fat in the prime rib cut was highest at 12 minutes following urea infusion for both the weaner and yearling group of cattle (r = -0,91 and -0,76, respectively). The relationships between urea space and the percentages of water, protein and ash in the prime rib cut, respectively, was also highest at the 12-minute post-infusion time for both groups. When urea space and carcass specific gravity were correlated, the correlation coefficient was highest when calculated from the data obtained from the 12-minute post-infusion time for both the weaners (r = 0,77) and yearlings (r = 0,71).

In the analysis of the results, carcasses were divided into two groups according to cold carcass mass. The heavy group consisted of carcasses which exceeded the mean mass of all carcasses (201,5 kg) and the light group included all carcasses with a mass below the mean. This grouping brought about the transfer of older animals of poor finish into the light carcass group and young animals of good finish into the heavy carcass group. Of the various estimates of urea space, the US-12 value gave the highest correlation coefficient with the fat percentage of the prime rib cut for both carcass groups (r =-0,71 and -0,82, respectively). Similarly, the US-12 measurement gave the highest correlation with carcass specific gravity, but only for the heavy carcass group (r= 0,78). This latter relationship was less satisfactory for the light carcass group (r = 0,36).

The carcasses were also divided into thin and fat by using the overall mean of 21,5 percent fat in the prime rib cut as the dividing point. The results show good correlations between US-12 and prime rib fat percentage for both thin and fat carcass groups, giving correlation coefficients of -0,67 and -0,75, respectively. The relationships between urea space and carcass specific gravity were satisfactory for fat cattle ($r = 0,61$) but less satisfactory for thin cattle, ($r = 0,27$).

It is clear, therefore, that urea space measurements calculated from plasma samples drawn 12 minutes after urea infusion show the highest correlation coefficient between urea space and percentage fat in the prime rib regardless of whether the animals were grouped according to age, cold carcass mass or fatness. Similarly urea space measurements estimated from plasma samples taken 12 minutes after infusion are strongly correlated with carcass specific gravity estimates, at least for carcasses from weaners, yearlings, fat cattle and cattle giving heavy carcasses. The relationships are weaker for cattle with a light carcass mass and for thin cattle, but the 12 minute sampling time remains the most favourable.

The relationships between the constituents of the prime rib and carcass specific gravity on a basis of age, cold carcass mass and fatness of the cattle were also obtained. The results presented indicate that light carcasses, and those grouped as thin, generally show low correlations between

the constituents of the prime rib and carcass specific gravity. Such correlations are higher for carcasses from yearlings, for heavy carcasses and for carcasses from fat cattle.

When the data were arranged into four almost equal groups on the basis of increasing cold carcass mass, significant relationships between percentage fat in the prime rib cut and US-12 were obtained with all the groups. Significant relationships between carcass specific gravity and US-12 were obtained in all but the lightest carcass group (mean prime rib fat content of approximately 14 - 15 percent). The percentage fat in the prime rib was also strongly correlated with carcass specific gravity in all but the lightest carcass group. The results, therefore, provide good evidence that light carcasses with a low degree of fatness, approximately 14 - 15 percent fat in the prime rib cut, do not give very reliable results with the specific gravity technique.

A prediction equation of percentage fat in the prime rib on US-12 was established and is presented in this thesis. A multiple regression analysis was carried out on the data to determine whether live mass affected the relationship between urea space and fat percentage of the prime rib. The analysis showed that the inclusion of live mass as a factor in the equation did not bring about any significant improvement.

The urea dilution technique, as described in this investigation,

may provide an inexpensive, simple and reasonably accurate means of assessing body composition in live cattle. Urea appears to meet most of the requirements of a satisfactory tracer for estimating body composition in live animals. More work in this field is therefore necessary in order to refine the urea infusion technique for greater precision in assessing live animal composition.

The work described here comprises only the initial stages of a much wider field of investigation. However, there can be no doubt that a study of live animal evaluation holds exciting possibilities. Findings in this field of study must be exploited in practice since there is a great need for breeding cattle with a high proportion of lean meat and controlled amounts of fat, giving a product of high consumer acceptance.

The contribution of the findings to a clarification of some of the problems relating to body composition studies as a useful means to improve livestock for human consumption is discussed and possible lines of research indicated.

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APPENDIX 1

UREA INFUSION TECHNIQUE

A. Procedure

(i) Take initial blood sample with 30 ml plastic syringe and needle (gauge 12, length 5,08 cm).

(ii) Insert polyethylene catheter (Clay Adams PE 200) through needle into the jugular vein.

(iii) Infuse urea solution (approximately two minutes). Note time.

(iv) Flush catheter with a 0,9% saline solution.

(v) Take serial blood samples, noting precise time each blood sample is taken.

(vi) After each blood sampling, fill catheter with a heparin solution.

(vii) Save 50 ml sample of infused solution for determining the concentration of the solution.

(viii) Centrifuge samples.

(ix) Determine plasma urea nitrogen content of each sample.

B. Reagents

(i) Urea infusion solution : (20% urea solution in 0,9% saline)

200 g Urea (AR grade)
9 g NaCl

Make up to 1000 ml with distilled water.

(ii) Heparin solution for blood collecting tubes:

Dissolve 100,000 USP units of sodium or potassium heparin in 50 ml of distilled water. Place one drop of solution in blood collecting tube for each 10 ml of blood to be collected.

(iii) Heparin solution for flushing catheters :

5 ml heparin solution (ii)
0,9 g NaCl
Make up to 100 ml with distilled water.

C. Instruments and equipment

(i) Super-Ward Luer-Lok syringe (50 ml)

(ii) Three-way metal tap

(iii) Plastic syringes:
for blood sampling (20 - 30 ml)
for heparin and saline solutions (5 ml)

(iv) Polyethylene catheter (Clay Adams PE 200)

(v) Plastic bottle fitted with rubber stopper and glass tube for infusion solution

(vi) Needles : gauge 12, length 5,08 cm
gauge 16, length 3,81 cm

(vii) Rubber tubing

(viii) Volumetric flask for sampling of infusion solution (50 ml)

(ix) Beaker for cleaning syringes

(x) Heparinized test tubes

(xi) Clock with timer

(xii) Scissors

APPENDIX 2

METHOD FOR DETERMINING PLASMA UREA NITROGEN

(After Fawcett and Scott, 1960; Searcy et al., 1961)

A. Reagents

(i) Urease buffer (1000 ml):

a. Dissolve 7,11 g Na_2HPO_4 (anhydrous) in 400 - 500 ml demineralized-CO_2 free water.

b. Add 5,0g EDTA and dissolve.

c. Dilute to 1000 ml with demineralized-CO_2 free water.

d. pH should be 7,0.

(ii) Buffered urease solution (50 ml):

a. Add 40 mg urease (Sigma type III powder) to 50 ml urease buffer and dissolve. (NOTE : unless weighing paper is ammonia-free, do not rinse).

b. This solution is stable for approximately one month when stored at 2-10° C.

(iii) Phenol colour reagent (two litres).

a. Dissolve 20,0 g phenol in 1200-1400 ml demineralized water.

b. Add 100 mg sodium nitroprusside and dissolve.

c. Dilute to two litres with demineralized water.

d. Store in amber glass bottle at 2-10° C; solution is stable for six months when protected from light.

(iv) Alkaline-hypochlorite reagent (two litres):

a. Dissolve 10,0 g NaOH in 1200-1400 ml demineralized water.

b. Add 16 ml "Chlorox" (or 0,84 g Na hypochlorite).

c. Dilute to two litres with demineralized water.

d. Solution is stable for six months when stored in clear glass container at 2-10°C.

(v) Urea standards :

No.	Conc. urea-N	Preparation procedure
U-100	100 mg/100 ml	dissolve 0,2144 g urea (dry) in demineralized water, add 1 ml concentrated HCl and dilute to 100 ml with demineralized water.
U-40	40 mg/100 ml	dilute 40 ml of U-100 to 100 ml with demineralized water.
U-20	20 mg/100 ml	dilute 20 ml of U-100 to 100 ml with demineralized water.
U-10	10 mg/100 ml	dilute 10 ml of U-100 to 100 ml with dimineralized water.

B. Procedure

(i) Dispense 0,2 ml of buffered urease solution into each test tube (minimum 15 ml capacity). Disposable test tubes may be used. The total number of test tubes required is dependent upon the number of samples and standards to be run and the number of determinations for each sample and standard. Normally, duplicate determinations are sufficient.

(ii) Add 0,02 ml plasma to each tube using a calibrated Sahli hemoglobin pipette; wash out the pipette with the mixture in the respective tube at least three times. Be sure all mixture is blown out of pipette before removing it from test tube. To the blank tubes add 0,02 ml demineralized water using the above washout procedure. To the standard tubes, add 0,02 ml of the desired standard using the above washout procedure.

(iii) Place tubes in a covered water bath at 37°C for at least 15 minutes.

(iv) Add 5,0 ml of phenol colour reagent followed immediately with 5,0 ml of alkaline hypochlorite reagent and mix thoroughly.

a. The use of automatic pipetting syringes gives rapid and uniform dispensing of the reagent which is important for consistent results.

b. It is important that the alkaline hypochlorite solution be added immediately after the phenol colour reagent to <u>each</u> sample; the optical density is diminished if the two reagents are not added promptly after each other. On the other hand, the two colour reagents cannot be mixed prior to adding to the sample because they are unstable.

(v) Replace the tubes in the covered water bath at $37^{\circ}C$ for at least 15 minutes.

(vi) Read optical density (or direct concentration) of samples and standards at 625 nm using the blank to zero the spectrophotometer.