ESTIMATION OF THE PERCENTAGE OF FAT AND LEAN IN THE EDIBLE PORTION OF STEER CARCASSES

by

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INTRODUCTION

The trend in American diets in recent years has been away from consumption of large amounts of animal fat (6, p. 1-2). The pork producer has borne the brunt of the impact so far, as reflected in the value of butcher hogs. This same effect is being felt in the beef industry as a result of the packers and butchers finding themselves unable to realize as much for beef tallow as they are paying for butcher cattle. This loss is inevitably reflected in the price which is paid to the producer for slaughter cattle.

The deposition of excess fat on meat animals is an expensive, uneconomical and unnecessary practice. Fat contains two and one-quarter times as much energy (26, p. 39-44) as protein or carbohydrate and, as stored in the animal, contains very little water. Considerably more nutrients are required, therefore, to add a pound of gain in the form of fat than in the form of lean meat.

It is a well recognized fact that fat, especially marbling (35, p. 319), is related to quality in beef. However, the degree to which an animal must be finished in order to have desirable eating quality is not well established.

Studies of the development of meat animals as affected by breeding, feeding, and management are primarily concerned with changes in fat deposit, the muscle system and skeletal structure. The percentage of fat, lean and bone in an animal at any given stage of development is of practical interest to the producer, packer, retailer and especially the consumer. Since fatness greatly affects the acceptability of meat to the consumer and since the fattening period is the most costly phase of animal production, it is imperative that a rapid and economical method of estimating the physical and chemical composition of carcasses be available to workers in the field of livestock and meat research.

Hankins and Titus (13, p. 450-468) concluded from the results of a study carried out by them that studies of meat animals are not complete without a determination of the body composition of those animals.

The most accurate method of determining the composition of a meat animal or a carcass is the chemical analysis of the entire animal, with contents of the digestive tract and bladder eliminated, or of the carcass. The techniques for this type of analysis were established many years ago (22, p. 493-680) and the results are very accurate. Unfortunately, this type of analysis is too expensive and time consuming to lend itself to any extensive investigation. Other investigators (14) (24, p. 727-755) have found that the composition of certain cuts from the beef carcass give quite accurate predictions of the composition of the entire animal or carcass. These methods considerably reduce the time and money necessary to acquire a given set of data. However, there still remains the problem of establishing a quick, inexpensive and relatively accurate method of establishing the composition of beef animals and carcasses.

In approaching the problem of establishing a fast, accurate method of determining the percentage of the various gross components of beef carcasses, recourse has first been taken to the scientific literature. Discussions of various methods of evaluating carcass composition of meat animals have been reviewed and reported herein.

In addition, experimental results are presented involving several methods of estimating the fat and protein in the edible portion of beef carcasses. The results of these experiments have been evaluated in terms of the accuracy of the estimate, and are used as a basis for recommendations concerning the usefulness of these methods in livestock and meat research.

REVIEW OF LITERATURE

Methods Used in Beef Carcass Studies

In recognition of the essentiality of knowledge concerning the composition of meat animals, a number of investigators have worked on the problem. Several methods relating to beef have been developed. The most frequently cited and extensive investigation of analysis of whole animal bodies was carried out by Lawes and Gilbert (22, p. 493-680) in the latter half of the nineteeth century. Their work is an example of the extremely accurate but very expensive and time consuming method of obtaining data.

Murray (27, p. 174-181) made an observation early in this century that has since served as the basis for many of the methods used in estimating the composition of meat carcasses and cuts. He stated that, "The composition of the non-fatty matter is practically constant. It is the same in cattle, sheep and pigs and is not affected by condition but varies slightly with age. The averages, as deducted from Lawes and Gilbert's analyses, are as follows:

	Ash %	Protein %	Water %
Young animals (calves, lambs and pigs)	3.75	19.35	76.9
Adult animals (cattle and sheep)	5.60	21.84	72.6

The composition of the whole body is therefore determined by the amount of fat in it." Hopper (17, p. 239-268) in an extensive study confirmed these basic findings and stated that, "The chemical composition on the ether extract free basis is a function of age with small regression coefficients. For some purposes the mean might be considered practically a constant. For practical application the small variance with age should be recognized in using composition on the ether extract-free basis as a means of predicting the water, ash and crude protein in the empty body, carcass and edible portion."

From the preceding observations it is not surprising that Lush (24, p. 727-755) found that the fat content in the entire live steer could be estimated from the dressing percentage by the use of the following equation: Per cent of fat in the entire live animal = 1.782 x dressing percentage -86.40. The correlation coefficient was +.84 ± 0.04. However, Lush noted that if the animals outside the fifteen to thirty per cent range of true fat, which would include most market animals, were excluded from these figures the correlation would be much lower. He, therefore, concluded that dressing per cent is not very reliable within narrow limits of fatness. In an attempt to alleviate this shortcoming he suggested the following equation for estimating the fat content of the live animal from the percentage of caul fat: Percentage of fat in the entire live animal = 14.55 x percentage of caul fat based on live weight + 5.19 which has a correlation coefficient of +.89 ± 0.03 between predicted and actual percentages.

Trowbridge and Moulton reached the conclusion, as reported by Lush (24, p. 727-755), that the composition of the wholesale rib cut rather adequately represented the carcass. The wholesale rib cut is also referred to as the standing rib or prime rib and includes the sixth through the twelfth rib. Lush (24, p. 727-755) found that the most reliable indicator of fatness of the entire animal was the percentage of fat in the edible portion of the wholesale rib cut. He gave the following estimating equation: Percentage of fat in the live animal = 0.603 x Percentage of fat in the rib flesh + 3.92. This prediction equation gives results which have a correlation coefficient of + 0.987 ± 0.003 with actual results. He also noted that sex and slaughter have less effect on estimates of body composition when using the rib. Hopper (17, p. 239-269) in a study of data derived from the analysis of 92 cattle reported the relationships that could be used to estimate the physical and chemical composition of the empty body, carcass and edible portion of the carcass from the analysis of the rib cut. In recognition of the need of a smaller sample as a source of information for estimating composition he included in his study the ninth, tenth and eleventh rib and the edible portion thereof as indicators of the physical and chemical composition. Numerous relations, some of which show extremely high correlation coefficients, and estimating equations are presented. In summarization he states, for example, that the physical composition of the whole and edible portion of the wholesale-rib, and ninth-tenth-eleventh-rib cuts, are highly correlated with the physical composition of the empty body, carcass and edible portion of the carcass. Likewise, the correlations for chemical composition of these same parts are high. The correlations are especially high for the percentage of fat.

Hankins and Howe (14), workers in the Bureau of Animal Industry, United States Department of Agriculture, have carried out one of the most extensive investigations of the relationship of the physical and chemical composition of various parts of the beef carcass to the carcass as a whole and to other parts thereof. Included in this study were correlations between: (1) the fatness of the ninth-tenth-eleventh rib and the standing rib, (2) the physical and chemical composition of the ninth-tenth-eleventh rib and the composition of the dressed carcass, (3) the fatness of various primal cuts and that of the carcass, (4) fatness of the ninth-tenth-eleventh rib and that of the sixth-seventh-eighth-twelfth rib sample and of each of the primal cuts. From these relationships the authors have derived many predicting equations, listing the standard error of each estimate, the coefficient of correlation and the probable error of each coefficient of correlation.

This work by Hankins and Howe (14) confirmed the findings of previous workers concerning the validity of the ninth-tenth-eleventh rib, hereinafter referred to as 9-10-11th rib, as an adequate sample of the carcass upon which to base predicting equations. Their comparison of the fat content of this cut to the fat content of the previously accepted standing rib cut showed a correlation coefficient of +.99 ± 0.003, with the following prediction equation: Per cent of ether extract in the edible portion of standing rib cut = 0.947 x per cent of ether extract in edible portion of 9-10-11th rib cut -0.750. The standard error of the estimate is 1.58 per cent.

Prediction equations for carcass composition of steers based on the composition of the 9-10-11th rib cut are listed in Table 1. The authors in their publication (14) also included the same equations for heifers and combine the two sets of data and derive equations for cattle regardless of sex.

The high degree of correlation which has been shown

TABLE 1

Relationship Between Chemical Composition Factors of the Ninth-Tenth-Eleventh-Rib Cut and Other Such Factors of the Same Cuts, as Well as Chemical Composition Factors of the Dressed Carcass (14)

Relationships Studied	Coefficient of Correlation and Probable Error	Estimating Equation	Standard Error of Estimate
Ether extract of edible portion of ninth-tenth-eleventh-rib-cut with -			
Ether extract of edible portion of dressed carcass	+ 0.91 ± 0.01	Y = 3.49 + 0.74X	2.52
Ether extract of eye muscle of ninth-tenth-eleventh-rib cut	+ 0.59 ± 0.05	Y = -5.18 + 0.26X	1.78
Protein of edible portion of ninth-tenth-eleventh-rib cut	- 0.93 ± 0.01	Y = 22.25 - 0.22X	0.65
Water of edible portion of ninth-tenth-eleventh-rib cut	- 0.99 ± 0.002	Y = 77.76 - 0.81X	0.95
Ether extract of the eye muscle of ninth-tenth-eleventh-rib cut with -			
Ether extract of edible portion of dressed carcass	+ 0.58 ± 0.05	Y = 20.58 + 2.04X	5.09
Protein of the edible portion of the ninth-tenth-eleventh-rib cut with -			
Protein of edible portion of dressed carcass	+ 0.83 ± 0.02	Y = 6.19 + 0.65X	0.79
Water of the edible portion of ninth-tenth-eleventh-rib cut with -			
Water of the edible portion of dressed carcass	+ 0.92 ± 0.01	Y = 16.83 + 0.75X	1.90
Protein of the edible portion of ninth-tenth-eleventh-rib cut	+ 0.91 ± 0.01	Y = 1.17 + 0.27X	0.76

to exist between the 9-10-11th rib cut and the composition of the carcass has brought this method of estimating carcass composition into common usage.

In an attempt to simplify the problem of estimating carcass composition, several other methods of objectively evaluating and estimating the composition of beef carcasses have been studied. The cross section of the longissimus dorsi muscle, referred to as the "rib eye", is used extensively by research workers as a standard procedure in evaluating carcass merit in beef cattle (31, p. 957-960). Cahill et al. (4, p. 701) demonstrated a highly significant correlation ($r = 0.853$, $n = 40$) between the cross-sectional area of the longissimus dorsi taken between the 12th and 13th rib and the edible portion of the carcass. Schoonover and Stratton (31, p. 957-960), in a study of the photographic grid used to study rib eye area, found a high correlation ($r = 0.86$, $n = 47$) between the ratio of rib eye area to the rib eye area plus area of external fat and the specific gravity of the ninth-tenth-eleventh rib cut. Wuthier and Stratton (34, p. 961-966) established that the rib eye area is correlated to both the lean in the 9-10-11th rib cut ($r = 0.79$) and to the specific gravity of that cut ($r = 0.94$).

Backus (3) in an investigation of the usefulness of the specific gravity of the excised *longissimus dorsi* muscle from the 9-10-11th rib as an objective measure of beef carcass eating quality found that there was a highly significant correlation between the specific gravity of this cut and carcass grades from Prime through Commercial. He also concluded that the specific gravity of this cut gives a reliable estimate of per cent of fat contained in the rib eye. Liuzzo, *et al*. (23, p. 513-520) using guinea pigs as a subject found carcass specific gravity correlated to the following: per cent fat in the carcass (r = 0.99), per cent water in the carcass (r = 0.97), per cent protein in the carcass (r = 0.96) and per cent ash in the carcass (r = 0.65).

A quick and simple method of objectively evaluating carcasses, which is implicated in other methods (31, p. 957-960) (34, p. 961-966) but is seldom used directly, is a measure of the average fat thickness over the rib eye. Cavender (7) demonstrated a significant difference between grades, Prime through Utility, for average fat thickness over the rib eye at the twelfth rib.

Methods Used in Pork Carcass Studies

It has been previously mentioned that the pork industry was first and most extensively affected by the production of excessively fat carcasses. Consequently, the effort directed towards the development of means of estimating the composition of pork carcasses has been much more extensive than has been the work with beef carcasses. Recourse has therefore been taken to the scientific literature to determine which methods of estimating the composition of pork carcasses have proven most successful and which of these methods might be applicable to the same problem with beef carcasses.

Hankins and Ellis (12, p. 257) demonstrated a significant ($P < 0.01$) positive correlation between the thickness of backfat and the per cent of fat in the edible portion of the pork carcass and reported that the fat content of the edible portion of the carcass can be estimated from the backfat thickness, using the following equation: Percentage of fat in the edible portion of the carcass = 22.45 + 0.691 x average thickness of backfat. This correlation has been borne out by other workers (25, p. 1-49) (28, p. 481-484) and is now an accepted tool in pork research work.

Another commonly used method of evaluating pork carcasses is the yield of "lean cuts"--weight of trimmed shoulder, loin and ham. Since beef primal cuts are not customarily trimmed, this method of evaluation seems to have very little application to the estimation of the composition of beef carcasses.

Several workers (12, p. 257) (8, p. 203-212) (15, p. 1269) (13, p. 450-468) (16, p. 763) have demonstrated a highly significant correlation ($P < 0.01$) between the specific gravity of pork carcasses and their percentage of fat. Some of these workers (12, p. 257) (13, p. 450-468) have also demonstrated that the specific gravity of certain primal cuts is significantly correlated to the specific gravity of the whole carcass as well as to several other estimates of carcass composition.

Several workers (20, p. 659-663) (25, p.1-49) (28, p. 86-92) (30, p. 85-92) have demonstrated that the cross sectional area of the longissimus dorsi muscle taken at the tenth rib is an useful indicator of the yield of lean cuts. Whiteman and Whatley (33, p. 591) have further stated that the size of the loin eye muscle determines the real value of the pork loin. Pearson et al. (29, p. 896-901) have further demonstrated that ratio of fat area to lean area of the cross section of the rough loin is sufficiently correlated to several other measures of carcass composition to be useful when other more accurate measures are not available.

Aunan and Winters (2, p. 319-325) used a hollow coring device for taking samples from various locations on the hog carcass and found that these samples gave highly significant indications of lean to fat ratio in the carcass. This work was based upon the results of the physical separation into lean, fat and bone of 121 carcasses supplemented by cut out values on 999 carcasses. From these data the authors determined that the composition of the carcass could be estimated by the following equations: Percentage of fat in the carcass = 25.1635 + 0.2353 (Percentage of fat in the last rib probe) + 9.6013 (Average backfat thickness) - 0.0387 (carcass weight); percent of lean in carcass = 75.1268 - 0.7754 (estimated percentage of fat in the carcass); per cent of bone in the carcass = 100 - (percentage of fat + percentage of lean). These estimates follow quite closely the true values as determined by physical separation.

Some of the sources of error that have been found to be of importance in pork studies might well be considered in setting up experiments with beef. Lasley and Kline (21, p. 485-489) in a study of 222 barrow carcasses found that the left side yielded significantly ($P < .01$) heavier hams, picnics, lean cuts and primal cuts but lighter bellies and Boston butts than the right side. These variations were due to splitting differences and they suggest that where it is impractical to use the average of both sides, which reduces variance, then one side should be used consistently. Aunan and Winters (2,

p. 319-325) also noted that cutting errors introduced large variance in the yield of primal cuts.

Another source of variance, pointed out by Fredeen et al. (11, p. 435-444) in a study of 1384 gilt and 1384 barrow carcasses, is the difference of fat to lean characteristics due to sex variances. Gilts, in this study, had an average backfat thickness of 1.33 inches and a loin eye area of 3.96 square inches while the same measures on barrows showed 1.44 inches of backfat and 3.42 square inches loin eye. In other studies (9, p. 91-94) (10, p. 95-99) the same workers found the same things true of a variety of breeds under various feeding programs. Herbert and Crown (15, p. 1269) in a study of carcass characteristics of barrows and gilts found that the gilts have a significantly higher per cent of ham and loin, a larger area of loin eye, more separable lean in the ham and thicker lean in the ham while barrows have a thicker backfat and more separable fat in the ham.

The high degree of correlation that these many authors have found to exist between the various chemical and physical components of carcasses confirms Murray's (27, p. 174-181) early observation that, "The composition of the non-fatty matter is practically constant." Callow (5, p. 174-199) concluded that at any given level of fatness the percentage of muscular tissue is the same for cattle, sheep and swine. Also, that when the carcass contains over eighteen per cent fatty tissue the percentage of all other tissues decreases as the per cent of fatty tissue rises. Because of this interdependency of the percentage of these various components it is possible to derive mathematical equations to predict the composition of carcasses from the knowledge of its content of one component. The percentage of fat is the most accurate single component to use in deriving such equations (17, p. 239-268).

EXPERIMENTAL

A knowledge of the composition of beef carcass is very valuable both to commercial workers and researchers. Methods of estimating the composition of beef carcasses and the edible portion thereof have been well established. However, those methods which are reasonably accurate are also quite expensive to carry out.

The experiment reported here was designed to establish reasonably accurate methods of estimating the composition of steer carcasses by techniques which can be carried out quickly and inexpensively, using a minimum of laboratory equipment. The methods used in this experiment were chosen for investigation because they meet these criteria.

EXPERIMENT I

Methods and Materials

Samples for this experiment were obtained from thirty-two grade Hereford and Aberdeen Angus steers selected from animals used in cooperative feeding investigations. The animals from which these samples were taken were originally obtained by the cooperating group from several diverse herds.

The animals were slaughtered at a commercial abattoir where the normal commercial practices of taking warm carcass weights, shrouding the carcasses and chilling them at temperatures of approximately thirty-four degrees Fahrenheit for forty-eight hours before cutting were followed. The right forequarter of each carcass was cut "Chicago-style", and from the rib primal cut so produced the ninth-tenth-eleventh-twelfth rib cut was purchased. A tracing was made of the cross-section of the rib at the twelfth rib for fat and lean area determinations with planimeter; the thickness of external fat was also determined from these tracings. This part of the experiment was conducted at the packing plant, following which the samples were double wrapped in wax paper, put in stockinettes and shipped to the laboratory for further study. The samples were stored in a cooler at approximately 34°F.

until all analyses were complete.

In removing the twelfth rib from the previously mentioned sample the knife follows the posterior edge of the eleventh rib so that the 9-10-11th rib cut is taken from the prime rib (sixth through twelfth ribs, inclusive) by crowding the rear edge of the eighth and eleventh rib. The specific gravity of these samples (using a scale accurate to one gram) was determined by the water method, according to the following formula:

$$\text{Specific Gravity} = \frac{\text{air weight}}{\text{air weight - water weight}}$$

Two pairs of probe samples one-quarter inch in diameter were taken from each of the 9-10-11th rib cuts; one pair between the eighth and ninth ribs and one pair between the tenth and eleventh ribs. One of each of these two pairs of probes was taken through the deepest portion of the longissimus dorsi muscle and will hereinafter be referred to as the eye probe, the other of these two pairs of probes was taken through the center of the seam of fat which separates the longissimus dorsi and longissimus costarum muscles from the obliquus abdominus externus and latissimus dorsi muscles perpendicular to the rib and will hereinafter be referred to as the side probe. The location of these probes is illustrated in

Plates 1 and 2.

The location of these various probes was chosen in an endeavor to sample the muscular tissue, the external fat and the intermuscular fatty tissue. The eye probe not only samples the longissimus dorsi muscle but several smaller muscles as well as the intermuscular fatty tissue which separates them and the external fat. The site of the side probe was chosen to yield a composite sample of seam fat and external fat. However, as can be seen from Plates 1 and 2, it may also contain samples of the intercostal muscle, external intercostal, longissimus costarum, serratus dorsalis, and longissimus dorsi.

A hollow stainless steel probe, which is shown in Plate 3, was used for obtaining the probe samples. The fatty tissues were easily and uniformly cut by this instrument, however the lean tissue was not, and a great deal of care in sampling the latter proved necessary. By keeping the instrument very sharp and using a slow rotating thrust it was possible to obtain what appeared visually to be a reasonably accurate cut of the lean tissue.

The core samples were physically separated into fat and lean tissue and weighed on an analytical balance which is accurate to .0001 g. The percentage of fat and

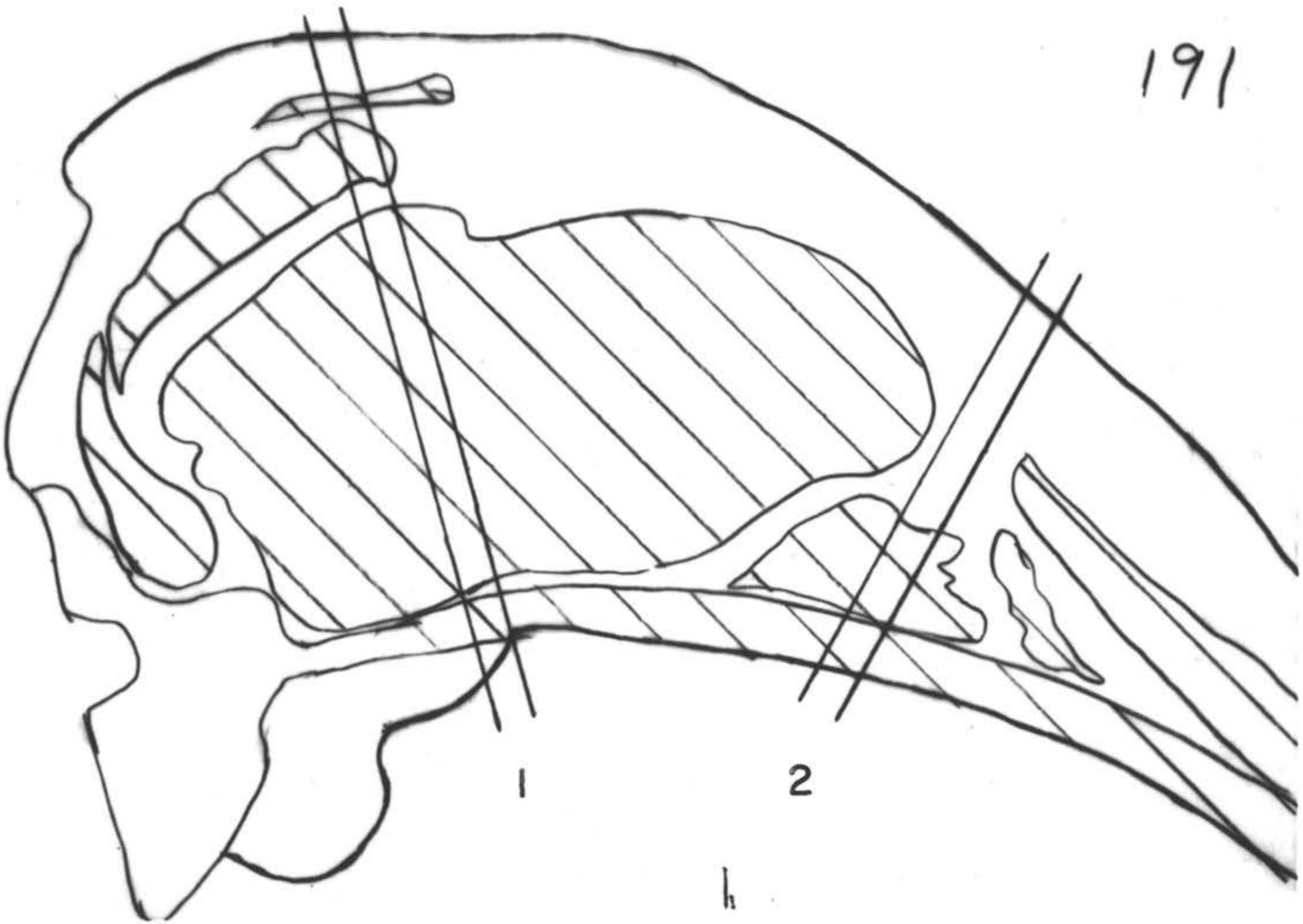


PLATE 1. Cross sectional tracings of the rib cut taken between eighth and ninth rib showing the location of the 8-9 eye (1) and side (2) probes.

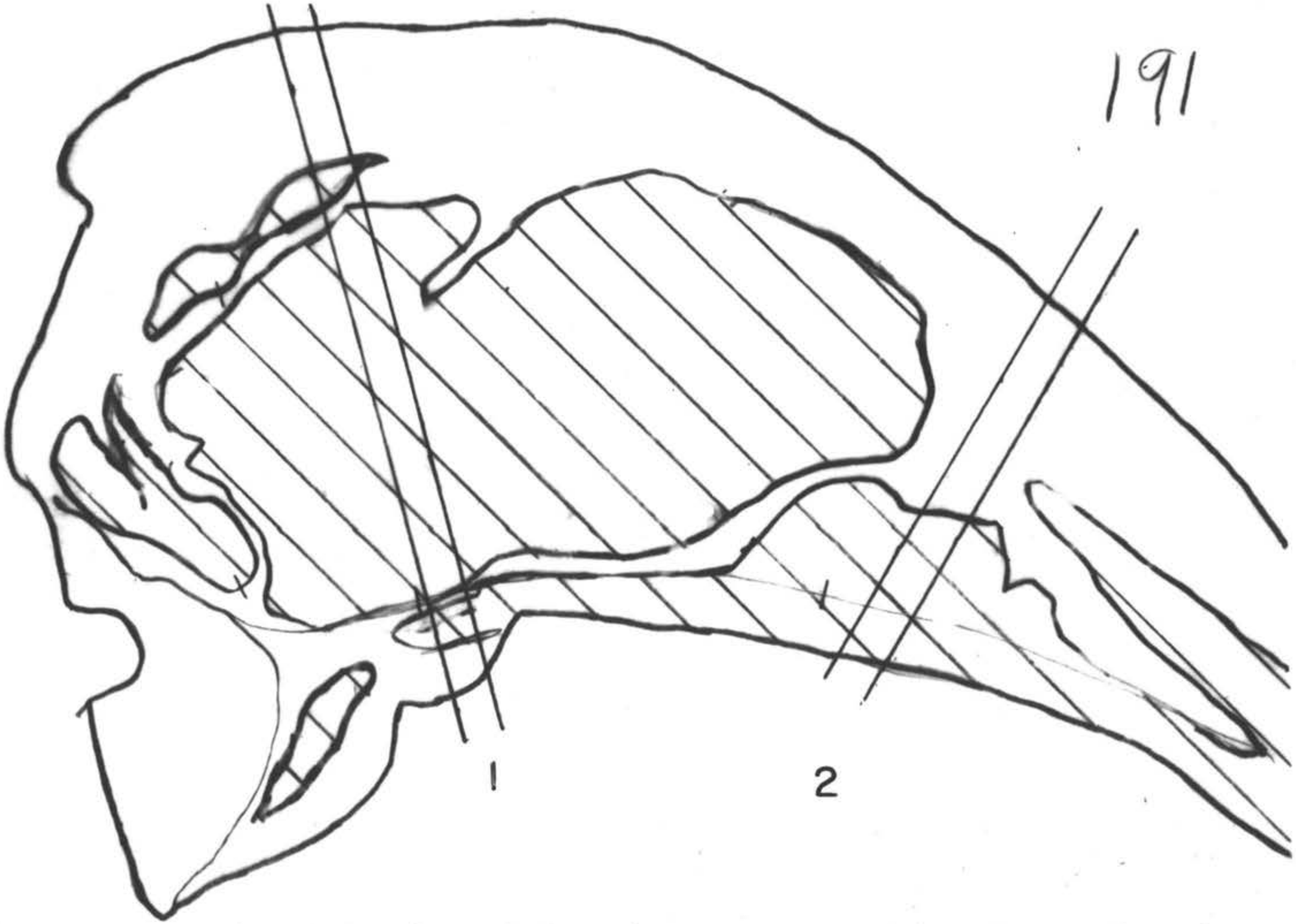
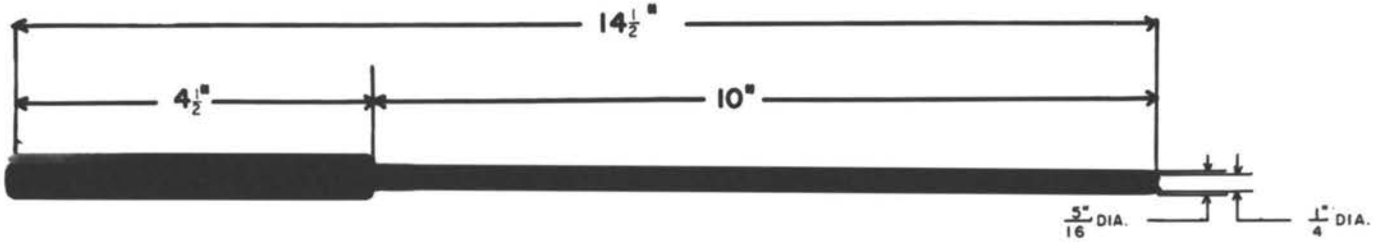
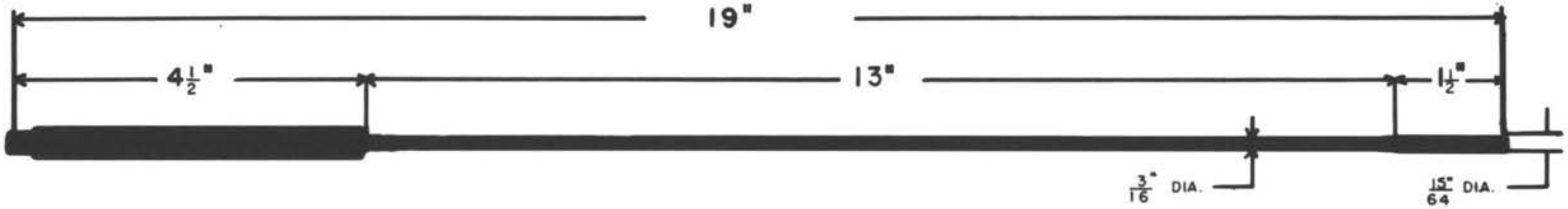


PLATE 2. Cross sectional tracing of the rib cut taken between the tenth and eleventh rib showing the location of the 10-11 eye (1) and side (2) probes.

PLATE 3



The instrument used in taking probe samples.



Plunger for removing sample from probe.

lean was determined for each individual probe and for the following combination of probes: the two side probes, the two eye probes, the side and eye probe taken between the eighth and ninth rib, the side and eye probe taken between the tenth and eleventh rib and the four probes combined. The percentage of fat and lean in these various combinations of probes was determined from the sum of the fat and lean tissues previously determined for the individual probes.

After the previously mentioned measures and samples were taken from the 9-10-11th rib cut the cuts were carefully boned out and the bones promptly weighed. The fat and lean tissue was ground five times in a grinder using a plate with one-sixteenth inch holes; the material was thoroughly mixed after each grinding and after the final grinding a sample was taken at random, placed in a glass jar, and kept in the refrigerator or frozen until analyzed. For analysis the entire contents of the jar were carefully mixed before the sub-samples were taken.

Protein, fat and water determinations were made according to the methods of the Association of Official Agricultural Chemists (1, p. 12-387) with the following exception:

In protein determinations the method of the Association of Agricultural Chemists (1, p. 12) was used with the following modifications recommended by Oldfield[1]: (a) The distillate was collected in 4% boric acid; (b) the indicator was composed of 0.1% bromcresol green in 95% ethyl alcohol (10 ml.) and 0.1% methyl red in 95% ethyl alcohol (2 ml.). Four gram wet samples were used in this determination and it was necessary to use 50 cc. of sulfuric acid to insure complete digestion.

Fat determinations were run, using the modified Babcock method (19, p. 273-276) after first running a preliminary study to confirm the accuracy of the Babcock method compared to the ether extraction as reported in the literature (18) (19, p. 273-276). The results of this comparison are given in Table 2.

All data were analyzed statistically by the method of least squares.

Results and Discussion of Experiment I

The data obtained from the thirty-two steers used in experiment one are presented in Table 3. There were thirteen U.S. Standard, thirteen U.S. Good and six U.S. Choice carcasses. The warm carcass weights were used in this experiment to eliminate the additional variation

[1] Oldfield, J. E. Unpublished modifications of the Kjeldahl procedure, Corvallis, Oregon State College, Animal Nutrition Laboratory, Department of Animal Husbandry, 1952.

TABLE 2
Comparison of Ether Extraction and Modified Babcock
Methods of Determining Fat Content

Samples	Percentage of Fat Ether Extraction	Modified Babcock
1	38.30	38.5
2	45.74	44.8
3	38.28	37.6
4	37.53	37.6
5	38.19	34.5
6	35.21	34.9

TABLE 3

Ranges, Means, Standard Deviations, and Coefficients of Variation of Data from Experiment One (n = 32)

Measurements	Range		Mean	Standard Deviation	Coefficient of Variation
Surface Area					
% Fat Area	17.67	42.53	28.57	6.8432	23.95
% Lean Area	57.47	82.33	71.42	6.8432	09.58
Area of *Longissimus Dorsi* (sq. in.)	6.06	11.98	9.64	1.4446	14.99
Area of Fat (sq. in.)	2.00	6.99	4.11	1.2486	30.78
Area of Lean (sq. in.)	6.63	12.29	10.06	1.9604	19.49
Thickness of Fat over *Longissimus Dorsi* (1/64 in.)	7.0	29.0	15.53	6.7313	43.34
Specific Gravity of 9-10-11 Rib	1.0507	1.0947	1.07166	0.0119	01.11
Weight of Fat in Probe (g)					
8-9 eye	0.2786	.9491	0.5897	0.1787	30.30
8-9 side	0.2828	1.1188	0.6856	0.21705	31.66
8-9 eye + side	0.5998	2.0678	1.2750	0.1082	08.49
10-11 eye	0.2429	1.0558	0.5309	0.1918	36.13
10-11 side	0.3272	1.1622	0.6529	0.2024	31.00
10-11 eye + side	0.6246	2.2100	1.1838	0.1128	09.53
Total 2 eyes	0.5944	1.9969	1.1212	0.3055	27.25
Total 2 sides	0.6358	2.2810	1.3526	0.3835	28.35
Total 4 probes	1.4806	4.2778	2.4585	0.6458	26.27
% Fat 9-10-11 Rib	17.10	44.8	32.71	6.4948	19.86
% Protein 9-10-11 Rib	12.50	18.28	14.90	1.3592	09.12
% H_2O in 9-10-11 Rib	41.33	61.79	51.647	4.3700	08.46
Warm Carcass Wt.	318.0	620.0	464.16	77.3645	16.67
% Bones in 9-10-11 Rib	13.10	23.59	18.13	2.3066	12.72

which results from varying percentages of shrink due to varying degrees of finish. The carcass weights ranged from 318 to 620 pounds with a mean of 464.16 pounds and a standard deviation of 77.3645 pounds. This mean weight is lower than that customarily found for slaughter steers and was brought about by including several animals which had been fed a ration which was sub-optimal in energy level for a finishing ration. The ranges, means and standard deviations of the chemical analyses and of the various samples taken are also presented in Table 3. The correlation coefficients between the measures taken and percentage of fat and protein in the 9-10-11th rib cut are presented in Table 4.

Cross-sectional tracings of the rib cut taken between the twelfth and thirteenth ribs show a considerable variation in area of _longissimus dorsi_ muscle, area of fat and area of miscellaneous lean. The miscellaneous lean includes the following muscles: _longissimus costarum_, _spinalis dorsi_, _trapezius_ and _multifidus dorsi_. The variation in size of these areas is shown in Plates 4, 5, and 6. The area of fat is the most variable and has a coefficient of variation of 0.3078. The area of _longissimus dorsi_ muscle is the least variable and has a coefficient of variation of 0.1499. This same relationship

TABLE 4

Correlation Coefficients Between Predictive Measures and Percentage of Fat and Protein in the 9-10-11th Rib Cut Experiment I, n = 32)

Measurements	% Fat r	% H_2O	% Protein r
Surface Area			
% Fat Area	0.6298		-0.5891
% Lean Area	-0.6298		0.5891
Area of *Longissimus Dorsi* (sq. in.)	0.1144		-0.0329
Area of Fat (sq. in.)	0.7800		-0.6682
Area of Lean (sq. in.)	0.1028		0.0669
Thickness of Fat over *Longissimus Dorsi* (1/64)	0.6866		-0.6101
Specific Gravity of 9-10-11 Rib	-0.8569		0.7421
Weight of Fat in Probe (g)			
8-9 eye	0.6362		-0.6049
8-9 side	0.8345		-0.7134
8-9 eye + side	0.8567		-0.7624
10-11 eye	0.6546		-0.5952
10-11 side	0.8153		-0.7429
10-11 eye + side	0.8151		-0.7460
Total 2 eyes	0.7756		-0.7262
Total 2 sides	0.8884		-0.7689
Total 4 probes	0.8917		-0.8050
% Fat 9-10-11 Rib		0.9232	-0.9277
% Protein 9-10-11 Rib	-0.9277	0.8457	
% H_2O in 9-10-11 Rib	-0.9232		0.8457

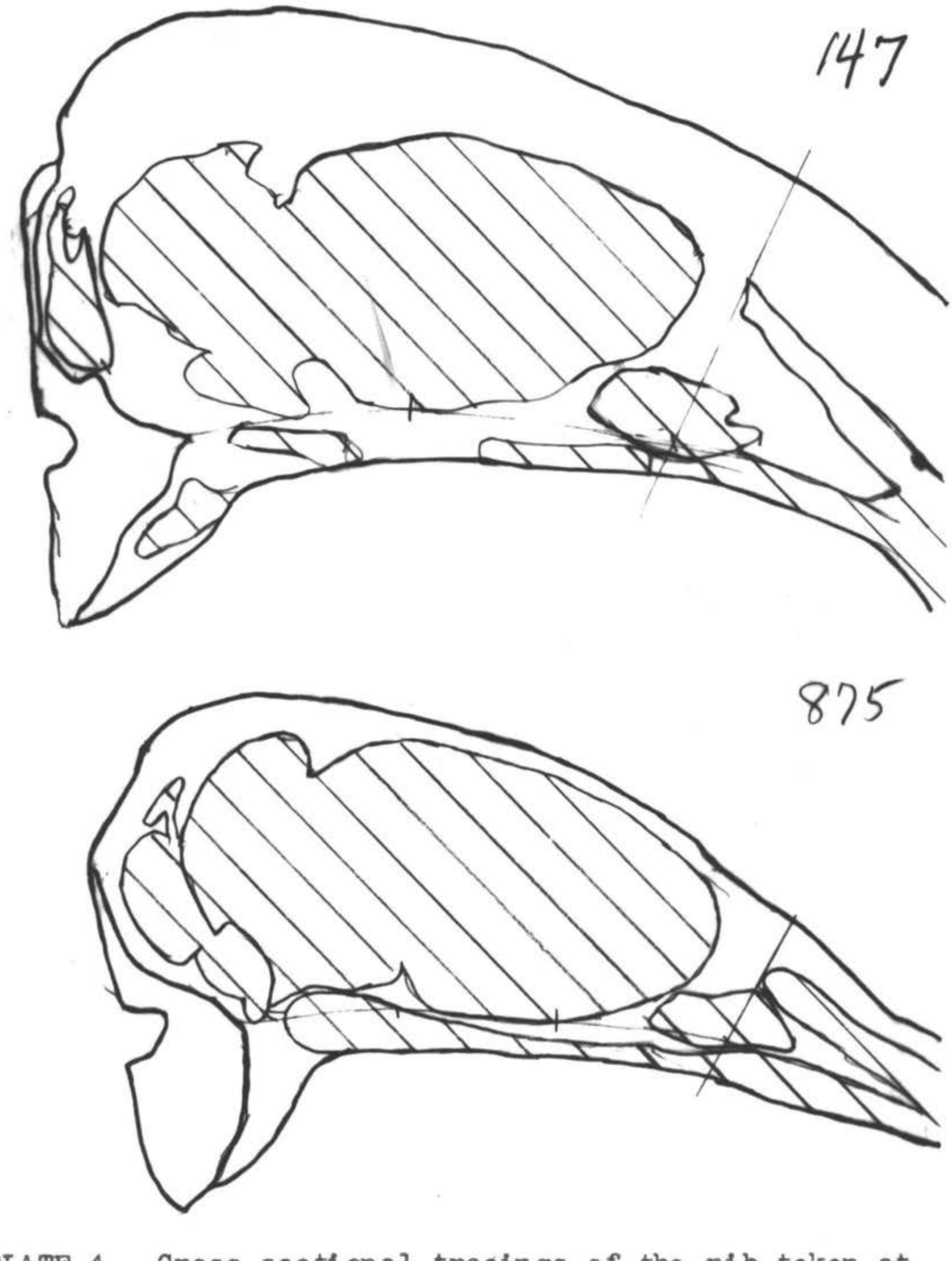
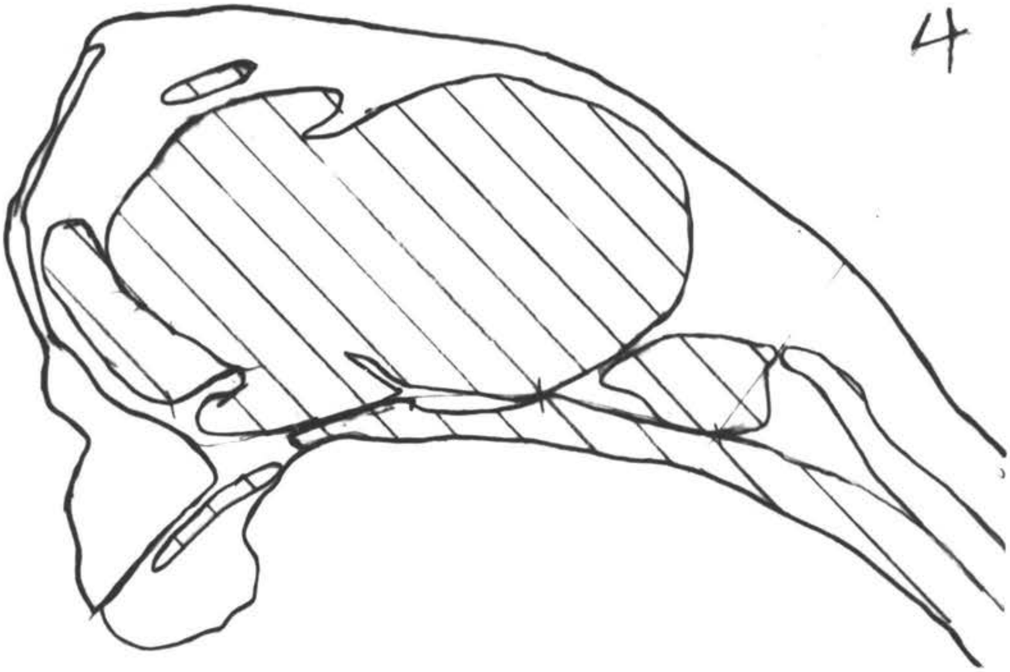


PLATE 4. Cross sectional tracings of the rib taken at the twelfth rib. Note the difference in area of fat.



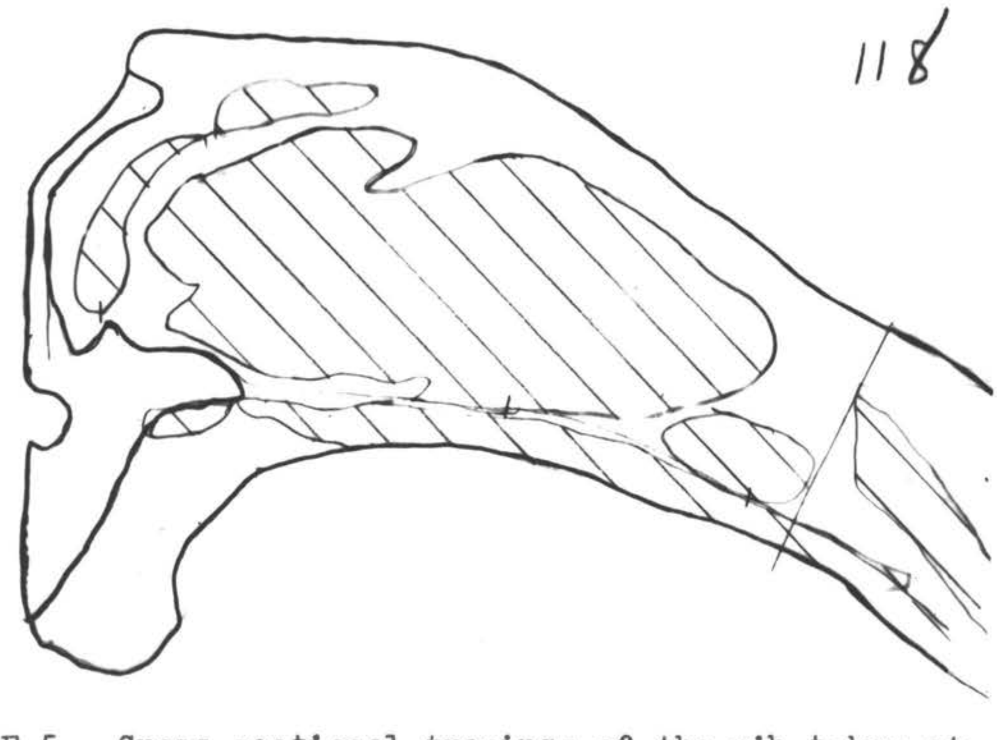
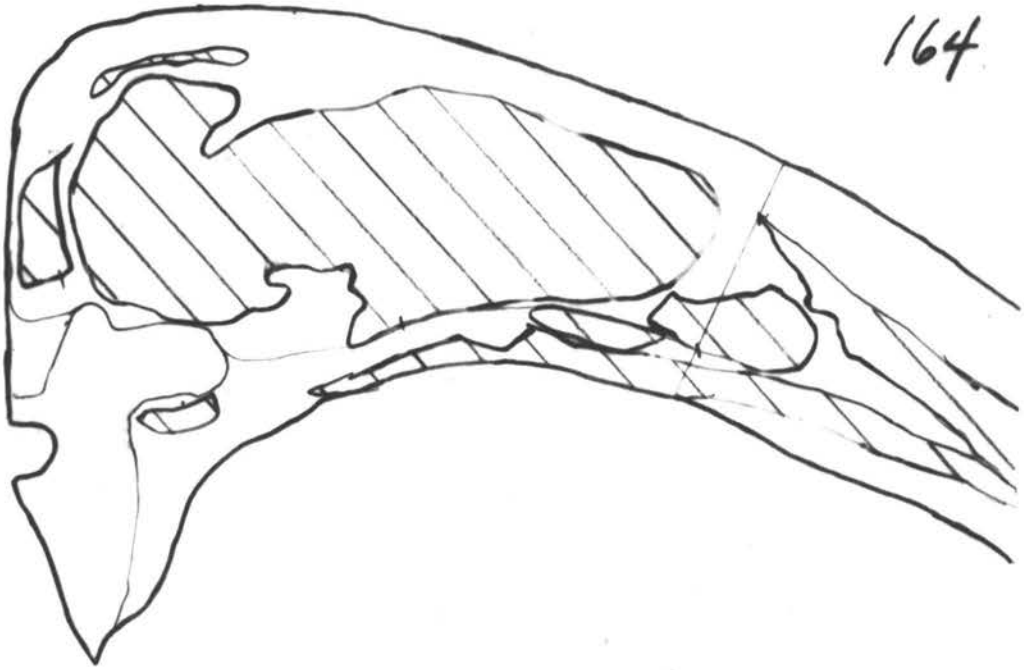


PLATE 5. Cross sectional tracings of the rib taken at the twelfth rib. Note the difference in area of longissimus dorsi.



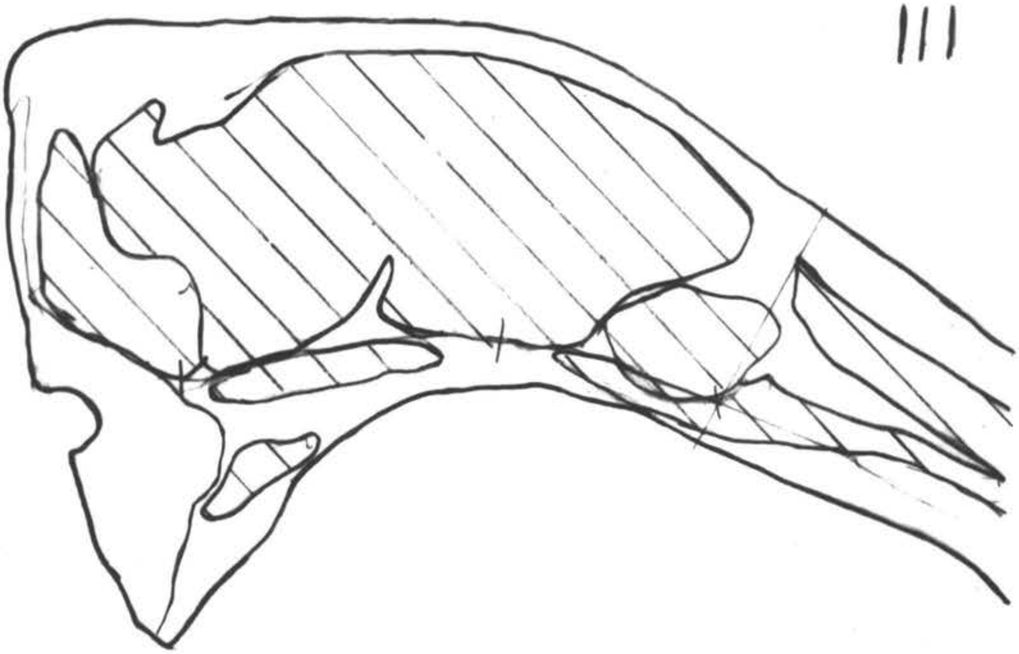


PLATE 6. Cross sectional tracings of the rib taken at the twelfth rib. Note the difference in miscellaneous lean (other than <u>longissimus dorsi</u>).

of variation carries over into the percentage of fat and lean area.

The correlation coefficients between the percentage of fat and lean area and the percentage of fat and protein, by chemical analysis, of the 9-10-11th rib cut are of sufficient magnitude to serve as a basis for constructing prediction equations if no better estimate is available. However, they lack the precision which is necessary when working within narrow ranges of difference. Neither the area of the <u>longissimus dorsi</u> muscle nor the total lean area is significantly correlated to the fat or protein content of the 9-10-11th rib. This fact does not mean that these measures are useless in evaluating beef carcasses, since it is the lean content of the carcass that determines its true value. It does show, however, that the lean area does not increase in proportion to increases in body weight brought on by finishing cattle. On the other hand, the area of fat was more highly correlated to both protein and fat of the edible portion of the 9-10-11th rib cut than was the percentage of fat area.

The thickness of fat cover over the <u>longissimus dorsi</u> muscle was correlated to percentage of fat and protein of the edible portion of the 9-10-11th rib cut to about the same magnitude as was the percentage of fat and lean area in the cross section of the rib. The development of a technique for measuring this fat cover on live animals would prove most useful in making quantitative estimates of live conditions.

The predictive value of the specific gravity of the 9-10-11th rib cut was higher in this experiment than were any of the values derived from the tracings of the cross-section of the rib cuts. It must be borne in mind, however, that these carcasses were split in a packing house by skilled workers and that variations in splitting will introduce large additional error to the values derived.

The percentages of fat in several of the probes and combinations of probes were sufficiently correlated to the percentage of fat and protein in the edible portion of the 9-10-11th rib cut to be very promising as a source of predictive information. However, difficulties encountered in obtaining probe samples of lean in the second experiment led to the determination of the correlation coefficient between the weight of fat in the various probes and combinations of probes and the fat and protein content of the edible portion of the 9-10-11th rib cut. As is shown in Table 5, the weight of fat in the probes is more highly correlated to the percentage of fat and protein in the edible portion of the 9-10-11th rib cut

TABLE 5

Correlation Coefficients Between Percentage of Fat in Probe and Weight of Fat in Probe With Percentage of Fat and Protein in the 9-10-11th Rib Cut (n = 32)

Measurements	% Fat r	% Protein r
% of Fat in Probes		
8-9 eye	0.5351	-0.5286
8-9 side	0.7594	-0.8160
8-9 eye + side	0.7225	-0.65429
10-11 eye	0.5030	-0.4819
10-11 side	0.6429	-0.6210
10-11 eye + side	0.6255	-0.6127
Total 2 eyes	0.6937	-0.6777
Total 2 sides	0.7205	-0.6463
G.T.	0.7887	-0.6240
Weight of Fat in Probes		
8-9 eye	0.6362	-0.6049
8-9 side	0.8345	-0.7134
8-9 eye + side	0.8567	-0.7624
10-11 eye	0.6546	-0.5952
10-11 side	0.8153	-0.7427
10-11 eye + side	0.8151	-0.7460
Total 2 eyes	0.7756	-0.7262
Total 2 sides	0.8884	-0.7689
G.T.	0.8917	-0.8052

than is the percentage of fat in the probes. Inasmuch as this is true in all but one instance, the weight of fat in the probes was used in determining prediction equations.

The side probes, both the 8-9 and 10-11, and the combinations including side probes are more highly correlated to both fat and protein of the edible portion of the 9-10-11th rib than are the eye probes or the combination of two eye probes. This probably results from the fact that the side probe samples both the intermuscular and external fat and so gives a more representative sample of the fat content. This is fortunate, since a sample taken at the location of the side probe does less damage to the carcass than taking a sample through the rib eye.

The correlation coefficients between predictive measures and chemical composition based on these 32 carcasses were of sufficient magnitude to warrant further investigation. Accordingly, data were obtained on 48 additional carcasses the succeeding year to provide a more extensive basis upon which to base prediction equations.

EXPERIMENT II

Methods and Materials

Experiment two was carried out in the same manner as experiment one with the following exceptions:

The tracings of the cross section of the rib cuts were made at the laboratory instead of at the packing plant. Due to the larger numbers of animals and crowded conditions at the packing plant it seemed reasonable to expect that more accurate tracings could be obtained at the laboratory.

Since it was impractical to carry out all sampling and analytical work on the fresh samples, all samples were frozen in order that they all be handled alike. The tracings and specific gravities were taken on the fresh rib cuts after which each cut was double wrapped in wax paper and sharp frozen in a room at -19°F. After remaining in the "sharp room" for 24 hours the cuts were stored at 0°F. until processing, which was carried out within two weeks. The cuts were thawed six at a time in a cooler at 34°F. It was found to be extremely difficult to obtain normal appearing probe samples from these rib cuts which had been frozen and thawed. This was particularly true of the lean tissues in that the probe sample was much shorter than the thickness of the cut would indicate as reasonable. This shortening appeared to be due to failure to obtain a full probe cut of the lean tissue. On the same basis of evaluation the probe samples of fat appeared relatively accurate.

Results and Discussion of Experiment II

The data obtained from the forty-eight steers used in experiment two are presented in Table 6. There were two U.S. Standard, thirty-two U.S. Good and fourteen U.S. Choice carcasses in this experiment. The warm carcass weights ranged from 433 pounds to 761 pounds, with a mean of 553.8 pounds and a standard deviation of 77.4 pounds. At these weights the carcasses fit well into the bracket of desirable carcass weights, known in the industry as "handy weight" cattle. The cattle used in this experiment had all been fed a finishing ration. The ranges, means and standard deviations of the chemical analyses and of the various samples and measures taken are also presented in Table 6. Those predictive measures which were found in experiment one not to be significantly correlated to the chemical composition of the edible portion of the 9-10-11th rib cut are not presented in the second experiment.

The correlation coefficients between the various measures taken and the fat and protein content of the

TABLE 6

Ranges, Means, Standard Deviations and Coefficients of Variation of Data from Experiment Two (n = 48)

Measurements	Range		Mean	Standard Deviation	Coefficient of Variation
Surface Area					
% Fat Area	22.90	51.06	36.04	6.0759	16.86
% Lean Area	48.96	77.10	63.96	6.0759	9.50
Area of *Longissimus Dorsi* (sq.in.)	7.61	11.93	9.75	1.8056	18.54
Area of Fat (sq. in.)	3.46	12.03	6.44	1.8233	28.31
Thickness of Fat Over *Longissimus Dorsi* (1/64 in.)	15.0	62.0	31.46	10.7068	34.03
Specific Gravity of 9-10-11 Rib	1.0185	1.0854	1.0582	0.0151	1.43
Weight of Fat in Probe (g)					
8-9 eye	0.2312	0.8568	0.5156	0.1539	29.85
8-9 side	0.3331	1.2165	0.7240	0.1833	25.32
8-9 eye + side	0.6798	1.8674	1.2396	0.2612	21.07
10-11 eye	0.3254	1.0328	0.5901	0.1709	28.96
10-11 side	0.2891	1.1914	0.6755	0.1978	29.28
10-11 eye + side	0.8261	1.9281	1.2655	0.2969	23.46
Total 2 eyes	0.6512	1.8330	1.1069	0.2571	23.23
Total 2 sides	0.8719	2.2900	1.3983	0.3381	24.18
Total 4 probes	1.5278	3.6220	2.5052	0.4965	19.82
% Fat 9-10-11 Rib	25.10	48.60	35.79	5.7461	16.06
% Protein 9-10-11 Rib	11.10	16.75	13.89	1.2258	8.83
% H_2O in 9-10-11 Rib	39.83	56.50	48.25	4.0960	8.49
Warm Carcass Wt.	433.0	761.0	533.854	73.4416	13.26
% Bone in 9-10-11 Rib	11.31	20.69	15.19	2.0270	13.34

edible portion of the 9-10-11th rib cut are presented in Table 7. A study of the correlation coefficients which exist between the various areas of the cross sectional tracing of the rib and the protein and fat content of the rib shows that three of the measures estimate the protein and fat content approximately equally, that is, percentage fat area, percentage lean area and thickness of fat over the longissimus dorsi muscle. Since the measuring of the thickness of the fat cover is very simple and can be done quickly and accurately it should be the most useful of these measures in obtaining an estimate of carcass composition. It is interesting to note that the area of fat is not as highly correlated to chemical composition in the heavier and more highly finished animals as it was to the lighter, less finished animals in experiment one.

The specific gravity of the 9-10-11th rib cut is significantly correlated to the chemical composition of the edible portion of the same cut. However, the magnitude of the correlation is not sufficient to make it as valuable a predictive measure as those previously mentioned.

The percentage of fat in the probe samples was not significantly correlated to the percentage of fat or protein in the edible portion of the 9-10-11th rib cut. As

TABLE 7

Correlation Coefficients Between Predictive Measures and Percentage of Fat and Protein in the 9-10-11th Rib Cut (Experiment II, n = 48)

Measurements	% Fat r	% H_2O	% Protein r
Surface Area of the Rib			
% Fat Area	0.7013		-0.6816
% Lean Area	-0.7013		0.6816
Area of Fat (sq. in.)	0.6495		-0.6267
Thickness of Fat over Longissimus Dorsi (1/64 in.)	0.6917		-0.6689
Specific Gravity of 9-10-11 Rib	-0.6443		0.6266
Weight of Fat in Probe (g)			
8-9 eye	0.2409		-0.2526
8-9 side	0.6736		-0.6228
8-9 eyes + side	0.6135		-0.5605
10-11 eye	0.4778		-0.4275
10-11 side	0.6848		-0.6479
10-11 eyes + side	0.7357		-0.6748
Total 2 eyes	0.4573		-0.4036
Total 2 sides	0.7692		-0.7177
Total 4 probes	0.7604		-0.7041
% Fat 9-10-11 Rib		-0.9695	-0.9414
% H_2O 9-10-11 Rib	-0.9695		0.9396
% Protein 9-10-11 Rib	0.9414	0.9396	

stated previously, considerable difficulty was experienced in obtaining what appeared to be a true sample of lean tissue. Since the fatty tissue did appear to yield an accurate sample it seemed reasonable that the weight of fat in the probe would serve as a predictive value to be used in estimating the chemical composition of the carcass. It was the solving of this problem which led to the use of the weight of fat in the probes instead of the percentage of fat in the probe. In agreement with the results given in Table 5 of experiment one, the weight of fat in the probe was found to be the best estimate of the chemical composition of the edible portion of the 9-10-11th rib cut. In experiment two as in experiment one, the side probes and those combinations of probes which included the side probes were most highly correlated to the chemical values which are to be estimated.

RESULTS AND DISCUSSION OF EXPERIMENTS I AND II COMBINED

The data obtained from the two experiments were combined for evaluation of their predictive value. The ranges, means, and standard deviations of the various samples taken and analyses made are presented in Table 8. The 80 steers used in this study comprise a weight range which would include a large majority of the slaughter cattle in the United States.

In studying the differences that occur between the animals in experiments one and two in area of fat and lean, it becomes obvious that the major difference is in area of fat. Although the mean carcass weight of the animals in experiment two was fifteen per cent higher than the mean carcass weight of the animals in experiment one, the area of the *longissimus dorsi* muscle increased only one per cent. This finding along with the highly significant negative correlation between carcass weight and percentage of protein in the edible portion of the 9-10-11th rib indicates that there is very little increase in protein in the edible portion of the carcass as the weight increases within this range.

The correlations which exist between the various measures taken and analyses made and the fat and protein content of the edible portion of the 9-10-11th rib and

TABLE 8

Ranges, Means, Standard Deviations and Coefficients of Variation of Data from All Carcasses Studied (n = 80)

Measurements	Range		Mean	Standard Deviation	Coefficient of Variation
Surface Area					
% Fat Area	17.67	51.04	33.05	7.428	22.48
% Lean Area	48.96	82.33	66.95	7.428	11.09
Area of *Longissimus Dorsi*	6.06	11.98	9.70	1.5064	15.53
Area of Fat	2.00	12.03	5.51	1.9763	35.87
Area of Lean	6.63	13.41	10.76	1.6801	15.61
Thickness of Fat over *Longissimus Dorsi* (1/64 in.)	7.0	62.0	25.09	12.1740	48.52
Specific Gravity of 9-10-11 Rib	1.0185	1.09471	1.0633	0.0155	01.46
Weight of Fat in Probe (g)					
8-9 eye	0.2786	0.9491	0.5453	0.1486	27.25
8-9 side	0.2828	12.165	0.7086	0.1986	28.03
8-9 eye + side	0.5998	2.0678	1.2537	0.2971	23.70
10-11 eye	0.2429	1.0558	0.5664	0.1820	32.13
10-11 side	0.2891	1.1914	0.6665	0.2000	30.01
10-11 eye + side	0.6246	2.2100	1.2328	0.3250	26.36
Total 2 eyes	0.5944	1.9969	1.1126	0.2778	24.97
Total 2 sides	0.6358	2.2900	1.3800	0.3579	25.93
Total 4 probes	1.4806	4.2778	2.4865	0.5035	20.25
% Fat 9-10-11 Rib	17.10	48.60	34.56	6.238	18.05
% Protein 9-10-11 Rib	11.10	18.28	14.30	1.3619	09.52
% H_2O in 9-10-11 Rib	39.83	61.79	49.61	4.4969	09.06
Warm Carcass Wt.	31.80	761.00	517.98	87.1133	16.82
% Bone in 9-10-11 Rib	11.31	23.59	16.37	2.5762	15.74

the carcass weight are presented in Table 9. Carcass weight was included in this table because it was found to be highly correlated both to the measurements to be used in prediction equations and to the chemical analyses of the 9-10-11th rib. The correlations which exist between the several measures of lean and fat area of the cross section of the rib are of similar magnitude and in the same direction as are the correlations in the two separate experiments. The slight differences that do exist are probably a result of having made the tracings in experiment two in the laboratory where it was possible to take more time and be more accurate in making the tracings than was possible when they were made at the packing plant in experiment one. Another possibility, which suggests itself too late to be answered in this experiment, is that the percentage of fat in the fatty tissues is probably higher in the more highly finished animals used in experiment two and is therefore a better estimate of the percentage of fat in the edible portion of the 9-10-11th rib cut.

The prediction equations which have been derived from single measures are presented in Tables 10 and 11 along with their coefficients of correlation and the standard deviations of the predicted values. Per cent fat area

TABLE 9

Correlation Coefficients Between Predictive Measures and Percentage of Fats and Protein in the 9-10-11th Rib Cut (Experiments I and II, n = 80)

Measurements	% Fat r	% H_2O r	% Protein r	Carc. Wt. r
Surface Area of the Rib				
% Fat Area	0.6832		-0.6997	0.5948
% Lean Area	-0.6832		0.6997	-0.4796
Area of Fat (sq. in.)	0.6750		-0.6884	0.7422
Thickness of Fat over Longissimus Dorsi (1/64 in.)	0.6513		-0.6839	0.6115
Specific Gravity of 9-10-11 Rib	-0.7288		0.6955	-0.6483
Weight of Fat in Probe (g)				
8-9 eye	0.3476		-0.2991	
8-9 side	0.7463		-0.6529	
8-9 eyes + side	0.6939		-0.5917	
10-11 eye	0.5738		-0.5229	
10-11 side	0.7312		-0.6625	0.6115
10-11 eyes + side	0.7738		-0.7021	0.5851
Total 2 eyes	0.5824		-0.5094	
Total 2 sides	0.8076		-0.7149	0.5662
Total 4 probes	0.8069		-0.7167	0.5366
% Fat 9-10-11 Rib		0.9460	-0.9360	0.6385
% H_2O 9-10-11 Rib	-0.9460		0.9127	
% Protein 9-10-11 Rib	-0.9360	0.9127		-0.6504

TABLE 10

Coefficients of Correlation, Prediction Equations and Standard Deviations Derived from the Relationship Between Predictive Measures and Percentage of Fat in the 9-10-11th Rib Cut (n = 80)

Measurements	Coefficient of Correlation*	Prediction Equation*	Standard Error of Estimate
Surface Area of the Rib			
% Fat Area	0.6832	Yf = 15.3716 + 0.5804X	4.58
% Lean Area	-0.6832	Yf = 80.3072 - 0.6834X	4.58
Area of Fat (sq. in.)	0.6750	Yf = 22.8351 + 2.1286X	5.65
Thickness of Cover Area Longissimus Dorsi muscle (1/64)	0.6513	Yf = 26.1825 + 0.3337X	4.33
Specific Gravity 9-10-11 Rib	-0.7283	Yf =347.1229 -293.8773X	4.30
Weight of Fat in Probes			
10-11 side	0.7312	Yf = 19.3643 +22.7918X	4.28
10-11 eye + side	0.7738	Yf = 16.2937 +14.8124X	3.99
Total 2 sides	0.8076	Yf = 15.0068 +14.1652X	3.66
Total 4 probes	0.8069	Yf = 12.1428 + 9.0136X	3.61

* All correlation and regression coefficients are statistically significant (P 0.01).

TABLE 11

Coefficients of Correlation, Prediction Equations and Standard Deviations Derived from Relationship Between Predictive Measures and Percentage of Protein in the 9-10-11th Rib Cut (n = 80)

Measurements	Coefficient of Correlation*	Estimating Equations*	Standard Error of Estimate
Surface Area of Rib			
% Fat Area	-0.6997	Yp = 18.5868 - 0.6997X	0.97
% Lean Area	0.6997	Yp = 5.6040 + 0.1298X	0.97
Area of Fat (sq. in.)	-0.6884	Yp = 16.9077 - 0.4744X	0.99
Thickness of Cover Area Longissimus Dorsi Muscle(1/64)	-0.6839	Yp = 16.2151 - 0.0765X	1.00
Specific Gravity 9-10-11 Rib	0.6955	Yp = 61.2228X- 50.8207	0.98
Weight of Fat in Probes			
10-11 side	-0.6625	Yp = 17.3028 - 4.5117X	1.03
10-11 eye + side	-0.7021	Yp = 17.9237 - 2.9427X	0.98
Total 2 sides	-0.7149	Yp = 18.0500 - 2.7203X	0.96
Total 4 probes	-0.7167	Yp = 18.5806 - 1.7232X	0.96

* All correlation and regression coefficients are statistically significant (P 0.01).

plus per cent lean area account for 100 per cent of the area used in this study of the cross section of the rib and are therefore correlated to one another at -1.0. With this relationship, their standard deviations are the same when used to predict the same component and their correlation coefficients differ only in sign, not in magnitude. The regression equations using per cent fat area as a prediction value are: (1) Percentage of fat in the edible portion of the 9-10-11th rib cut = 15.3716 + 0.5804 X percentage of fat area in the cross section of the rib, which has a standard deviation of 4.58 and a correlation coefficient of 0.6832; (2) percentage of protein in edible portion of the 9-10-11th rib = 18.5868 - 0.6997 X percentage of fat area in the cross section of the rib which has a standard deviation of 0.97 and a correlation coefficient of -0.6997. The regression equations using the percentage of lean area as a prediction value are: (1) Per cent fat in the edible portion of the 9-10-11th rib = 80.3072 - 0.6834 X percentage of lean area in the cross section of the rough loin which has a standard deviation of 4.58 and a correlation coefficient of -0.6832; (2) percentage of protein in the edible portion of the 9-10-11th rib = 5.6040 + 0.1298 X percentage of lean area in the cross section of the rib with a standard deviation of 0.97 and a correlation coefficient of 0.6997. These two sets of equations predict protein and fat with the same accuracy and precision. However, neither of them is accurate enough to detect small differences.

The surface area of fat in the cross section of the rib may be used to predict both protein and fat content of the edible portion of the 9-10-11th rib with very nearly the accuracy and precision of the percentage of fat area. This is made possible by the relative constancy of the lean area. The regression equations for this measure are: (1) Percentage of fat in the edible portion of the 9-10-11th rib cut = 22.1825 + 2.1286 X area of fat (sq. in.) in the cross section of the rib with a standard deviation of 4.64 and a correlation coefficient 0.6750; (2) percentage of protein in the edible portion of the 9-10-11th rib = 16.9077 - 0.4744 X area of fat (sq. in.) in the cross section of the rib cut with a standard deviation of 0.99 and a correlation coefficient of -0.6884.

The thickness of the fatty tissue covering the <u>longissimus dorsi</u> muscle has been successfully used for the prediction of fat in the carcasses of swine and is at the present time being studied (32, p. 3-10) as a means of live evaluation of beef cattle body composition.

Consequently, it was felt that the predictive value of this measure should be investigated in the present study. The thickness of fat cover over the <u>longissimus dorsi</u> muscle was measured in sixty-fourths of an inch. An average of three measures taken from the cross sectional tracings of the rib, made between the 12th and 13th rib, was used. This measure was found to be almost as highly correlated to the percentage of fat and protein of the edible portion of the 9-10-11th rib as were percentage of fat area, percentage of lean area or area of fat. The prediction equations are: (1) Percentage of fat in the edible portion of the 9-10-11th rib = 26.1825 + 0.3337 X the thickness of the fatty tissue over the eye muscle measured in sixty-fourths of an inch. The standard deviation of this prediction was found to be 4.33 with a correlation coefficient between thickness of cover over the rib eye and the percentage of fat in the edible portion of the 9-10-11th rib of 0.6513. Percentage of protein in the edible portion of the 9-10-11th rib = 16.2151 - 0.0765 X the thickness of fatty tissue over the eye muscle with a standard deviation of the prediction of 1.00 and a correlation coefficient between thickness of fatty tissue and percentage of protein of -0.6838.

Since carcass weight is significantly correlated to both the percentage of protein and the percentage of fat of the edible portion of the 9-10-11th rib, as shown in Table 8, it was felt that its inclusion in a prediction equation would increase the accuracy and precision of prediction. This measure lends itself particularly well to a study of simple methods of estimating the carcass composition of beef animals because it is readily available without additional study or analysis. The multiple regression equations including carcass weight are presented in Tables 12 and 13.

The inclusion of warm carcass weight with percentage of fat area in the rough loin makes one of the most accurate and precise prediction equations studied in these experiments. The multiple correlation coefficient of these two factors with percentage of fat in the edible portion of the 9-10-11th rib was found to be 0.8830 and with the percentage of protein in the edible portion of the 9-10-11th rib 0.6434. The standard deviations are 2.16 and 0.87 respectively. The regression equations are: (1) Percentage of fat in the 9-10-11th rib = 8.0450 + 0.3989 X percentage of fat area in cross section of the rib + 0.0257 X the warm carcass weight; (2) percentage of protein in the edible portion of the 9-10-11th rib = 20.1988 - 0.0898 X percentage of fat area in the cross

TABLE 12

Prediction Equations, Multiple Correlation Coefficients, Partial Correlation Coefficients and Regression Coefficients Pertaining to the Relationship Between Predictive Measures and Percentage of Fat in the 9-10-11th Rib Cut (n = 80)

X_1	X_2	$r_{13.2}$*	$r_{23.1}$*	R^2*	Prediction Equation*	Standard Error of Estimate
% of Fat Area in the Cross Section of the Rib (sq. in.)	Carcass Weight	0.4904	0.3950	0.8830	$Yf = 8.0450 + 0.3989X_1 + 0.0257X_2$	2.16
Thickness of Cover over the *Longissimus Dorsi* muscle (1/64 in.)	Carcass Weight	0.4284	0.3184	0.5036	$Yf = 16.0896 + 0.2055X_1 + 0.0257X_2$	4.45
Specific Gravity of 9-10-11 Rib	% Lean Area of the Cross Section of the Rib (sq.in.)	-0.5373	-0.5594	0.5805	$Yf = 264.0682 - 198.4403X_1 - 0.27566X_2$	4.09
Weight of Fat in Probe						
10-11 side	Carcass Weight	0.5596	0.3546	0.5726	$Yf = 11.887 + 16.9501X_1 + 0.0219X_2$	4.13
10-11 eye + side	Carcass Weight	0.6412	0.3616	0.6510	$Yf = 9.6832 + 11.6182X_1 + 0.0204X_2$	3.73
Total of 2 side probes	Carcass Weight	0.7032	0.3728	0.7811	$Yf = 5.9416 + 11.4851X_1 + 0.0247X_2$	2.96

* All correlation and regression coefficients are statistically significant (P 0.01).

TABLE 13

Prediction Equations, Multiple Correlation Coefficients, Partial Correlation Coefficients and Regression Coefficients Pertaining to the Relationship Between Predictive Measures and Percentage of Protein in the 9-10-11th Rib Cut (n = 80)

X_1	X_2	$r_{13.2}$*	$r_{23.1}$*	R^2	Prediction Equations*	Standard Error of Estimate
% of Fat Area in the Cross Section of the Rib (sq. in.)	Carcass Weight	-0.5123	-0.4900	0.6434	$Yp = 20.1988 - 0.0898X_1 - 0.0057X_2$	0.82
Thickness of Cover over the *Longissimus Dorsi* muscle (1/64 in.)	Carcass Weight	-0.4762	-0.4022	0.5262	$Yp = 18.2886 - 0.0502X_1 - 0.0053X_2$	0.95
Specific Gravity of 9-10-11 Rib	% Lean Area of the Cross section of the Rib (sq. in.)	-0.4737	0.5818	0.5640	$Yp = 35.0201X_1 + .0760X_2 - 28.0396X_2$	0.91
Weight of Fat in Probe						
10-11 side	Carcass Weight	-0.4405	-0.4138	0.4665	$Yp = 19.3897 - 2.8809X_1 - 0.0061X_2$	0.95
10-11 eye + side	Carcass Weight	-0.5220	-0.4149	0.5890	$Yp = 19.7726 - 2.0492X_1 - 0.0057X_2$	0.88
Total of 2 side probes	Carcass Weight	-0.5536	-0.4262	0.7349	$Yp = 20.4285 - 2.0171X_1 - 0.00644X_2$	0.71

*All correlation and regression coefficients are statistically significant (P 0.01).

section of the rib - 0.0059 X warm carcass weight.

The inclusion of warm carcass weight with thickness of cover over the rib eye did not materially alter the predictive value as compared to the use of a simple regression using thickness of cover alone. The standard deviation for the prediction of fat was increased 0.12 and for the prediction of protein it was reduced 0.05.

The specific gravity of the 9-10-11th rib cut was found to be more highly correlated to percentage of fat in the edible portion of the 9-10-11th rib cut than were any of the measures of the surface area of the rib. The relationship between specific gravity and percentage of fat in the edible portion of the 9-10-11th rib cut is represented by a correlation coefficient of -0.7288. Specific gravity is as highly correlated to percentage of protein in the edible portion of the 9-10-11th rib cut as are any of the surface area measures. The correlation coefficient between specific gravity and percentage of protein in the 9-10-11th rib cut is 0.6955. The regression equations are: (1) Percentage of fat in the edible portion of the 9-10-11th rib cut = 347.1229 - 293.8773 X specific gravity of the 9-10-11th rib; (2) per cent of protein in the edible portion of the 9-10-11th rib = 61.2228 X specific gravity of the 9-10-11th rib - 50.8207.

The standard deviations are 4.30 and 0.98 respectively.

Combining specific gravity and warm carcass weight in a multiple regression equation did not improve the prediction of either the percentage of fat or protein in the edible portion of the 9-10-11th rib cut. Specific gravity and percentage of lean area in cross section of the rib are both correlated in the same direction to both fat and protein content of the edible portion of the 9-10-11th rib. Using these two measures in a multiple regression equation improved the predictions of both percentage of protein and fat. The standard deviations obtained using these prediction equations, which are presented in Tables 12 and 13, are 4.09 and 0.91 respectively for percentage of fat and percentage of protein in 9-10-11th rib cut. These standard deviations are sufficiently larger than others from prediction equations which are more simply derived to make the use of the multiple regression of specific gravity and percentage of lean area on percentage of fat and protein relatively undesirable.

The weight of fat in several of the probe samples gave higher correlations with both percentage of fat and protein than were obtained from any other simple correlation of a single estimating measure. As can be seen in Table 9, those probe samples and combinations of probe samples which include side probes have the highest correlation to both percentage of fat and protein in the edible portion of the 9-10-11th rib. Those probe samples which are sufficiently highly correlated to percentage of fat and protein and which can be most easily located on the intact forequarter are used in the establishment of prediction equations. The simple prediction equations are presented in Tables 10 and 11 and the multiple regression prediction equations are presented in Tables 12 and 13.

The inclusion of warm carcass weight with weight of fat in the probe materially reduces the standard deviation of the predicted values. Since warm carcass weights are ordinarily available and add to the accuracy of predictions, the use of multiple regressions equation involving warm carcass weight and weight of fat in the probes is more desirable than the use of single regression equations based on weight of fat in the probes.

As was stated above, the two side probes have the highest correlation to the percentage of protein and fat of the edible portion of the 9-10-11th rib of any of the single probe samples. Consequently, the combined weight of the two side probes is the best predictive value of all those studied. The ranges, means, standard deviations, and correlation coefficients between weight of fat in the 8-9 and 10-11 side probes with the chemical composition of the 9-10-11 rib cut are almost identical for the two side probes. Therefore the increased accuracy obtained by combining the two samples is obtained from the averaging effect of the addition. The regression equation is: Percentage of fat in the 9-10-11th rib cut = 5.9416 + 11.4851 X total weight of fat in the two side probes (in grams) + 0.0247 X warm carcass weight. The multiple regression coefficient (R^2) for this prediction equation is 0.7811 with a standard deviation of 2.96.

The multiple regression coefficient using weight of fat in the two side probes and carcass weight is lower than the multiple regression coefficient of the prediction equation using percentage of fat area in the rib cross section and carcass weight. However, the partial correlation coefficient of weight of fat in the two side probes on percentage of fat in the 9-10-11th rib is the highest partial correlation coefficient obtained for all combinations studied. This higher partial correlation coefficient indicates a lower dependency of this prediction equation upon carcass weight. Therefore, it will be more accurate in predicting the fat percentage of carcasses in a narrow weight range than will those prediction equations with a lower partial correlation coefficient due to predictive measure and a higher partial correlation coefficient due to carcass weight.

The multiple regression equation using weight of fat in the two side probes and weight of carcass as predictive measures was the most precise of all the equations used for predicting percentage of protein in the 9-10-11th rib. The multiple correlation coefficient (R^2) of this equation was found to be 0.7349 with a standard deviation of 0.71. The regression equation is: Percentage of protein in the 9-10-11th rib = 20.4285 - 2.0171 X the weight of fat in the two side probes - 0.0064 X the warm carcass weight.

The prediction equations derived in this study have been designed to predict the protein and fat content of the edible portion of 9-10-11th rib cut. The values derived by the use of these equations may be used in determining the relative degree of fatness or leanness of carcasses. In order to transform these predicted values to percentage of protein and fat in the edible portion of steer carcasses, the prediction equations derived by Hankins and Howe (14, p. 14) should be used. Their regression equations are: (1) Percentage of fat in the edible portion of the carcass = 3.49 + 0.74 X the percentage of ether extract in the 9-10-11th rib cut; (2) percentage of protein in the edible portion of the carcass = 6.19 + 0.65 X the protein in the edible portion of the 9-10-11th rib cut.

SUMMARY AND CONCLUSIONS

1. A study of various methods of predicting the fat and protein content of the edible portion of the beef carcass was carried out. Two experiments were carried out in successive years. Experiment one involved 32 steer carcasses and experiment two involved 48 steer carcasses so that a total of 80 steer carcasses was studied. The carcasses used in this study ranged in grade from U.S. Standard through U.S. Choice and in weight from 318 to 761 pounds. There were no U.S. Prime carcasses used in this study nor does the weight range go high enough to include all animals which might be slaughtered for human consumption.

2. The 9-10-11th rib cut was accepted in this study as an accurate indicator of the composition of the entire carcass. It must be borne in mind when extrapolating from the composition of the 9-10-11th rib to the composition of the entire carcass that there will be additional error involved when predicted rather than actual composition of the 9-10-11th rib is used. Consequently, it would be better to use the predicted composition of the 9-10-11th rib rather than of the carcass in evaluating experimental results wherever possible.

3. The data derived from these experiments were combined for statistical analysis. The method of least squares was used in analyzing the data and prediction equations were derived from the regression equations so obtained. All regression coefficients used in prediction equations have been subjected to a test of significance and were found to be highly significant ($P < 0.01$).

4. The inclusion in multiple regression equations of warm carcass weight with the predictive values studied improved the efficiency of the prediction equations over simple prediction equations.

5. The protein content of the carcasses studied did not increase in proportion to the increase in carcass weight. This is evident in the highly significant ($P < 0.01$) negative correlation between percentage of protein in the 9-10-11th rib cut and carcass weight. This same observation is borne out by a comparison of the cross sectional area of the <u>longissimus</u> <u>dorsi</u> muscle and the warm carcass weight. For the carcasses used in experiment one there was no significant increase in cross sectional area of the <u>longissimus</u> <u>dorsi</u> muscle as the carcass weight increased above 400 pounds. This same pattern was evident in the carcasses used in experiment

two; however, the plateau was reached at about 450 pounds in these more highly finished carcasses. A further study of this relationship should yield valuable information concerning the weight at which cattle should be marketed for greatest nutritional economy.

6. The prediction equations, percentage of fat in the edible portion of the 9-10-11th rib = 8.0450 + 0.3989 X percentage of fat area in the cross section of the rib + 0.0257 X warm carcass weight (R^2 = 0.8830, standard error of estimate = 2.16) and percentage of protein in the edible portion of the 9-10-11th rib = 20.1988 - 0.0898 X percentage of fat area in the cross section of the rib - 0.0057 X warm carcass weight (R^2 = 0.6434, standard error of estimate = 0.82), gave very precise estimates of percentage of fat and protein. These prediction equations are sufficiently accurate to detect relatively small differences between groups of experimental animals.

7. Thickness of fat cover over the longissimus dorsi muscle is sufficiently correlated to percentage of fat (r = 0.6513) and percentage of protein (r = -0.6839) in the edible portion of the 9-10-11th rib cut to be useful as a simple estimate of carcass composition and to encourage further attempts to make this measurement

on live animals.

8. Specific gravity is more highly correlated to percentage of fat ($r = -0.7288$) in the 9-10-11th rib than are any of the measures of surface area of the rib the highest of which is 0.6832. No other predictive measure was found which would combine with specific gravity in a multiple regression equation so as to materially increase its predictive value.

9. The combined weight of fat in the two side probes is a highly satisfactory predictive measure for both the percentage of fat and protein in the edible portion of the 9-10-11th rib cut. In a simple regression equation, it is the most highly correlated ($r = 0.8076$) to percentage of fat in the edible portion of the 9-10-11th rib cut of all the measures studied. When combined with warm carcass weight in a multiple regression equation (percentage of protein in the edible portion of the 9-10-11th rib = 20.4285 - 2.0171 X weight of fat in two side probes - 0.0064 X warm carcass weight) it gave the highest correlation ($R^2 = 0.7349$) to percentage of protein in the edible portion of the 9-10-11th rib cut and had the lowest standard error of estimate (0.71) of all multiple regression equations studied. The partial correlation coefficient due to weight of fat in the two

side probes is the highest partial correlation coefficient ($r_{13.2}$ = 0.7032) obtained, which means that this prediction equation would be the most useful in narrower weight ranges.

10. The increased accuracy and precision of prediction equations obtained with the use of the weight of fat in probe samples as compared to previously reported simple determinations and the greater simplicity than previously reported equally precise prediction techniques suggests the desirability of further development of the probe technique. Further refinement of the probing tool should further reduce the experimental error.

11. The inclusion of carcass composition evaluation in genetic and nutritional studies will materially increase the value of such studies. The prediction equations presented in this paper make it feasible to carry out large scale carcass composition evaluation studies. Use of these predictive techniques should add materially to efforts to breed and feed beef animals which will yield a high percentage of desirable lean meat.

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