THE RELATIONSHIP BETWEEN SPECIFIC GRAVITY AND CERTAIN PHYSICAL CHARACTERISTICS OF THE PORK CARCASS

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INTRODUCTION

One of the basic problems confronting breeders and research workers who are endeavoring to improve carcass quality in swine is a means of measuring the proportion of fat to lean in the carcass.

Recent work with guinea pigs reveals a close association between the specific gravity and the fat content of the eviscerated carcass. Several studies in man have indicated a strong relationship between specific gravity and obesity. The low density of fat when compared to other body components indicates that there should be a high relationship between the fat content and the specific gravity of the pork carcass. The purpose of the present study was to investigate the possibility of using specific gravity as a measure of the fat content in the pork carcass.

In this study data from 66 pork carcasses were analyzed statistically to determine the relationship between the specific gravity of the carcass and certain physical characteristics. On 32 of the carcasses an analysis was made to determine the relationship between the specific gravity and the chemical composition of the carcass.

REVIEW OF LITERATURE

A search of the literature reveals that specific gravity has not been used to measure the fatness of the pork carcass. However, studies with other species of animals have shown fat to be the most variable body component and to largely determine the density of the carcass. Studies have indicated that fat is the most variable component in the pork carcass. If pork fat exerts an influence on carcass density similiar to that shown for other species, then the specific gravity of a pork carcass would be an indirect measure of fatness.

Rathbun and Pace (1945) describe a method for the determination of carcass specific gravity of guinea pigs by water displacement. They present data on 50 normal mature animals for which the specific gravity of the eviscerated body ranged from 1.021 to 1.096. The fat content of the carcasses varied from 1.5 to 35.8 percent of the body weight. From this study variations in body fat appear to be largely responsible for differences in carcass specific gravity. The correlation between ether extract and specific gravity of the carcass was -0.972. A regression of ether extract on specific gravity gave the equation (ether extract $= \frac{5.135}{\text{sp. gr.}} - 4.694$). The standard error of the regression was 1.87 percent ether extract.

Working with the guinea pig, Morales et al. (1945) obtained specific gravity values for each of five components of the carcass. The values obtained were: fat .921, bone 1.43, nervous tissue 1.05, skin 1.06, and muscle 1.066. These workers made the following assumptions: (1) fat is the carcass component subject to the widest variations; (2) muscle, skin, and nervous tissue (in the adult) are constant fractions of the mass of bone; and (3) the densities of skin and nervous tissue are approximately the same as that of muscle. Using these assumptions these workers developed equations for the gross composition of the guinea pig carcass from a knowledge of: (1) the carcass weight (2) the carcass density; (3) the densities of fat, muscle, and bone (4) and the ratios of muscle, skin and nervous tissue to bone. Theoretical values of total body fat were calculated by the use of these equations for different carcass specific gravities. These values when plotted against specific gravity formed a curve which when compared to the regression of Rathbun and Pace (1945) showed a constant discrepancy of slightly more than the standard error of the regression which was 1.87 percent ether extract. This slight descrepancy was thought to be due to some small undetected error in the method of carcass specific gravity determination.

Pace and Rathbun (1945) in a further study of their guinea pig data showed that the ratio of water and chemically combined nitrogen to body weight is constant when calculated on a fat free basis. Water was found to constitute 72.4 percent and chemically combined nitrogen 3.52 percent of the body weight.

Behnke et al. (1942) obtained values of specific gravity on 99 healthy Navy men ranging from 20 to 40 years of age. These workers concluded that corporeal density can be accurately measured by specific gravity usually within .004 of a unit by the method of hydrostatic weighing, provided a correction is made for air in the lungs. Values of specific gravity for this group of men ranged between 1.021 and 1.097. Low values for specific gravity indicated obesity and conversely high values indicated leanness. Individual loss in weight through exercise and a restricted diet was associated with an increase in specific gravity. They also found that a difference in circumferential measurements of chest and abdomen served as a criterion of obesity and was correlated with specific gravity. Variation in percentage of bone in relation to body weight, excluding fat, had a negligible effect on specific gravity.

Behnke and Welham (1945) in a further study of corporeal density as an index of obesity, obtained specific gravity values on a group of football players whose average weight was 200 pounds. The average specific gravity of these men was 1.080. According to the height-weight tables of the Army and Navy these men were unfit for military service, but according to their specific gravity and thoracic and abdominal measurements they were in the prime of physical condition.

From data on growing boys Zook (1929) showed that specific gravity increased from about 1.000 at five years to about 1.040 at nineteen years of age. He attributed this increase partly to the increase of muscle, bone, and mineral content of the bones, and in part to the inability of the younger boys to exhale completely.

Boyd (1933) found that specific gravity increases rectilinearly with both stature and age. She considered a low specific gravity to be an indication of obesity in the mature individual.

In developing an index in cattle for the relationships of body dimensions to weight of the animal, Yapp (1923) used a volumeteric method to determine the specific gravity of 11 cattle varying in age, weight, and condition. He found the mean specific gravity of these animals to be .9694 and the range of specific gravities to be from .9305 to 1.0194. He makes no mention of a correction for trapped air in the lungs or intestinal gases which should be made to give the true specific gravity of a live animal. It is possible that the failure to make this correction would account for these specific gravity values of cattle being lower than those found by Rathbun and Pace (1945) for the guinea pig and Behnke et al. (1942) for man.

Mitchell and Hamilton (1929) state that on a fat free empty weight, much of the variation in composition of a pigs carcass disappears. This indicates that the variation in carcass composition is largely due to varying percentages of fat. In fact after a weight of 150 to 175 pounds was reached under ordinary conditions, corresponding to an age of 25 to 30 weeks, the composition of pigs on a fat free basis was remarkably constant and unaffected by the system of feeding. The fat free composition of the carcass characteristic of maturity consisted of 75 to 76 percent water, 20 to 21 percent crude protein, and approximately 4 percent ash.

Scott (1930) states that the depth of fat covering on a pork carcass exerts a considerable influence on the percentage of wholesale cuts yielded by the carcass. As depth of fat increases the lean and bony cuts decrease while fat cuts increase in percentage of the total carcass. The longer the carcass upon which a layer of fat is distributed, the less is the effect on carcass yield percentages. As depth of fat covering increases, the percentage of fat in the fat tissue increases and the percentage of moisture and protein in the fat tissue decreases.

On 60 hogs ranging in final weight from 93 to 250 pounds, Hankins and Ellis (1934) found a correlation of .84 between the percentage fat in the total edible portion of the carcass and average backfat in milimeters. A regression equation calculated for this relationship was -- fat in total edible portion of carcass = 22.45 $+$ 6.91 X (ave. backfat thickness). They state that this relationship appears linear when applied to carcasses with backfat over 1.5 milimeters. The correlation coefficient between the fat content of the trimmed right ham and the fat content of the edible portion of the carcass was .93. Average backfat thickness when correlated with chilled weight and length of carcass yielded coefficients of .67 and .40, respectively.

On 214 hogs, Willman and Krider (1943) obtained a highly significant correlation of +.42 between the condition (fatness) as determined by the visual observation of the live hog and thickness of backfat on the carcass. In a later study these workers report little or no correlation between the fatness of the pig and the development of the loin eye muscle or the lean area in the end cut of the ham. However, the area of the loin eye muscle correlated with the weight of the ham (+.28) and with the lean area in the end cut of the ham (+.53) was found to be highly significant. Certain breed differences in carcasses were noted.

According to McMeekan (1941) the total weight of bone, muscle and fat in the bacon pig carcass can be estimated with a high degree of accuracy from the weights of these respective tissues in either the loin or the leg. A combination of these two cuts provide even higher correlations in each case than either alone. The correlations between the combined cuts and the carcass was +.92, +.98, +.98, respectively for bone, muscle, and fat. Carcass measurements taken before cutting were shown to be mainly indicative of skeletal development.

Hiner and Hankins (1939) in a study of ham conformation found that variations in ham conformation were due to combinations of factors rather than to single factors. Percentage of fat had more effect than any other single characteristic studied.

Dickerson et al. (1943) analyzed data on 278 Poland China hogs slaughtered at 225 pounds to determine the relationship between carcass conformation and value per unit of live weight as calculated from the yields and prices of wholesale cuts. Measurements reflecting external conformation indicated differences in fat thickness, and in length of bone and muscle rather than in muscle thickness; and hence were less accurate than measurements of muscling for predicting value per unit of live weight. The best measure of muscling for wholesale cuts was area of lean in ham crossection as calculated from ham circumference and thickness of ham fat. Area of loin crossection indicated muscling and value more accurately than did ham area, but required mutilation of the trimmed loin.

Hazel et al. (1943) concluded, from their study on 152 barrows averaging 225 pounds when slaughtered, that carcass conformation can be changed only slightly by varying the growth rate. They state that little is gained in genetic or nutritional studies by eliminating that portion of the variation in carcass measurements which can be attributed to the observed variation in growth rate.

Hankins (1940) in a study of carcass characteristics in relation to type of hog showed a difference of two-thirds of a grade between the small and intermediate and between the intermediate and large type (fed to the same final weight). The difference between large and intermediate types in carcass yield was small and not significant. However, between these two types and the small type the differences were highly significant. The increased gross yield of the small type hogs was associated with increased fatness. Thickness in back-fat, and plumpness of hams increased with a change in type from large to small. As type varied from large to small, there were increases in yields of bacon, skinned backfat, leaf fat, and fat trimmings. The combination of backfat, leaf fat, and fat trimmings showed highly significant differences among the three types. On the other hand, with the increase in fatness, there were decreases in yields of ham, loin and shoulder. Although the carcasses of the large type hogs yielded the highest percentage of the three most desired cuts they were the lowest in market grade and close to the border line of softness.

Weight of pigs as it affects gains and carcass qualities was studied by Loeffel et al. (1943). Five average pigs were slaughtered at the following weights: 150, 175, 200, 225, 250, 300, 350 and 400 lbs. Carcasses were dressed shipper style. Dressing yields were computed on the basis of hot weight. Four hundred pound hogs dressed 10 percent higher than 150 pound hogs. The average backfat of 150 pound hogs was .69 of an inch as compared with 2.44 inches for the 400 pound hogs. The amount of fat increased from 32.4 percent of the carcasses of the 150 pound hogs to 55 percent of the carcasses of the 400 pound hogs. The 150 pound hogs contained 51.5 percent of lean muscle, while the 400 pound group contained only 34 percent of lean muscle. The average composition of the carcass of a hog weighing 225 pounds as determined by mechanical separation was 44.33 percent fat, 43.48 percent lean, 7.58 percent bone and 4.20 skin. Chemical analysis on these carcasses revealed that as hogs increased in weight and fatness the percentage of water, protein, and ash in the loin flesh declined. No material change in firmness or palatability was noted with increasing weight.

On 75 hogs ranging in weight from 99 to 342 pounds, Warner et al. (1934) used the combined percentage yield of cutting fat and belly as an index of fatness and the combined percentage yield of untrimmed ham and loin as an index of leanness. The combined yields of the two fat cuts ranged from 14.6 to 37.1 percent and of the two lean cuts from 29.1 to 37.5 percent. The combined weight of cutting fat and belly when expressed as a percentage of the weight of the entire cold carcass and correlated with the percentage of fat in the edible portion of the carcass yielded a coefficient of $+.91$. This gives a coefficient of determination of .83, which means that 83 percent of the variation in the percentage yield of the two fat cuts was associated with corresponding changes in fat content of the carcass. The correlation coefficient between the fat content and the percentage yield of the trimmed belly combined with that of only the unskinned back fat was +.84. A correlation between the lean cuts and the fat content of the edible portion of the carcass was -.77. A fourth correlation in this study was made between the fat content and the ratio of the percentage yield of the two fat cuts to the two lean cuts. This gave a coefficient of +.92.

Proportional changes in the carcass composition of the bacon pig during growth was studied by McMeekan (1940). Bone showed the lowest rate of increase. Muscle had the greatest rate of increase up to 16 weeks when it was overtaken by fat, the rate of which had been increasing most rapidly. Fat maintained this higher relative rate of increase, with the result that at 24 to 28 weeks, about 50 percent more fat than muscle was being laid down in the body. At 16 to 20 weeks most of the bone and nearly all of the muscle in the bacon pig had developed. Normal weight gains after this point consisted largely of fat.

Data on 578 Poland Chinas, 114 Landrace, and 54 Landrace Poland China crossbred hogs were analyzed by Dickerson (1947) to determine the influence of heritable differences in rate and economy of gain on the composition of hog carcasses. Fat cuts, ratio of fat cuts to lean cuts, and depth of backfat were used as measures of carcass fatness. Heritable variation was considerably greater for the measure of fatness than for the measures of muscle and bone. The amount of variance due to the additive effect of genes was .52 for fat cuts, .59 for ratio of fat to lean cuts, and .54 for depth of backfat as compared to .29 for lean cuts. The coefficients of variability for the above four measurements were 8.1, 10.1, 11.5 and 3.7, respectively. While the heritability was high for length of carcass (.74) and length of hind leg (.58) both of which are indications of bone growth, the coefficient of variation was only 2.8. The coefficients of variability show a greater amount of variation in the percentage of fat cuts, than in the percentage of lean cuts, Heritable differences in rate of gain were mostly due to changes in rate of fat deposition rather than in rate of bone and muscle growth. The analysis of the data by covariance gave results in agreement with those given above. The genes which increased rate of gain did so by increasing the rate of fat deposition more than by increasing the rate of bone and muscle deposition. Rapid fat deposition and low feed requirements tended to be caused by the same genes, as shown by strong correlations of the sires influence on feed requirement with his effect on items indicating fatness (-.6 to -.7) and on yield of lean cuts (.6). A combination of less activity and large appetite was considered responsible for the hereditary association of lower feed requirement with more rapid fat deposition.

Winters et al. (1949) in a study of the effect of the plane of nutrition on the economy of production and carcass quality fed four lots of pigs at different levels of feed intake. The animals fed the restricted diet throughout the experiment produced the leanest carcasses and required less nutrients per unit of gain, when maintenance was taken into account. From these facts, it was deducted that less nutrients are required to produce a pound of lean meat than a pound of fat. These workers state"If this deduction is correct, then selection of breeding stock on the basis of economy of gain should be at least somewhat effective as a means of selecting animals that will yield a lean carcass." These workers recognize the fact that these findings are not in accord with Dickerson (1947).

Correlations were used by Aunan and Winters (1949) to study the variations of muscle, fat, and bone in 30 pork carcasses. Mechanical separation was used to determine the amounts of these components. Average backfat thickness when correlated with the fat content of the carcass gave a coefficient of +.79. When correlated with lean content of the carcass the relationship was -.63. These coefficients were significant at the 1 percent level. Dressing percentage was highly correlated with average backfat thickness (+.66). The yield of the five primal cuts was not associated with dressing percentage. Correlations between the lean area of ham and lean area of loin were highly significant but neither of these measurements were significantly correlated with lean content of the carcasses. However, when a partial correlation was used to eliminate differences in carcass weight, the correlation between lean area of the loin and lean content of the carcass was highly significant. The correlation between the percentage five primal cuts and lean content of carcass was positive and highly significant. Length of carcass was not significantly correlated with lean content of carcass. Weight per inch of length divided by average backfat thickness, was positive and highly significant when correlated with lean content of the carcass. When correlated with fat content of the carcass this factor showed a highly significant and negative relationship. With the variations in carcass weight removed by partial correlation weight per inch of length divided by backfat and lean content showed a higher positive relationship.

SOURCE OF DATA

The 66 carcasses used in this study were taken from the two groups of hogs. The 34 carcasses in Group I came from three inbred Duroc lines and their crosses produced in the Swine Breeding Project at the Oklahoma Experiment Station in cooperation with the Regional Swine Breeding Laboratory. The lines used in this study were lines 3, 5 and 7. They have been bred as closed lines since 1938, 1945, and 1945, respectively. The percentage of inbreeding in these lines are approximately 23% for line 3, 15% for line 5 and 22% for line 7. The line crosses were the result of crosses between these three lines. These hogs were on record of preformance test and were fed a standard ration.

The 32 carcasses in Group II came from outbred Duroc stock which were individually fed. This group of hogs consisted of four pigs from each of eight litters. The hogs were fed so that each pig would receive a ration differing in fat content from that of his litter mates. The rations contained 2, 4, 8 and 12 percent fat.

PROCEDURE

A. Slaughtering and Cutting Methods:

After reaching a weight of 215 to 235 pounds, the hogs were taken off feed for a period of 24 hours, then slaughtered at the college abbatoir. The shrunk live weights were taken just prior to slaughter.

The hogs were slaughtered regulation packer style; head removed, jowl left on the carcass, leaf fat taken out, and the back split.

After chilling for at least 24 hours, the carcass weight and the specific gravity was taken. The carcasses were then returned to the cooler for approximately 24 hours to allow them to reset before cutting. The effects of the chilling time and humidity of the cooler were not considered (Loeffel, et al. 1943).

Both halves of the carcass were divided into the wholesale cuts; ham, loin, belly, and shoulder. The regular hams were removed by cutting two inches in front of the aitch bone at right angles to the shank. The shoulder was separated by cutting across the third rib, perpendicular to the vertebral column. The loin was removed by cutting in a slightly curved line from the lower edge of the tenderloin muscle, on the ham end, to a point as near the backbone, as possible on the blade end. The spareribs were taken out and the belly trimmed to uniform width.

The shoulders were trimmed "New York style," the loin trimmed as uniformly as possible, and the ham skinned. Approximately 1/4 inch of fat was left on the skinned ham and the loin. The feet were removed at the hock and the knee.

B. Carcass Measurements:

All weights and measurements were made on both halves of the carcass, except those in Table III which were made only in the right half.

The measurements for backfat and carcass length were taken in the chilling room. Other measurements were taken on the cutting table.

Length of carcass was measured from a point at the forward edge of the first rib, to the lower portion of the aitch bone as the carcass hung from the rail.

Average backfat was determined from three measurements on each side of the carcass. These measurements were taken parallel with the floor on a level with the third rib, the last rib and the sixth lumbar vertebra.

The loin was out at the last rib and the area of loin eye was calculated as the product of the width times the depth of the eye muscle at this point.

The area of lean in the ham face was calculated as the product of the width times the depth of lean at the point of removal from the carcass.

The primal cuts included the ham, loin, shoulder, and belly, the yield of these cuts were expressed as a percentage of the chilled carcass weight.

The lean cuts included the ham, loin, and shoulder and were expressed as a percentage of the chilled carcass weight.

The fat cuts included the belly and the fat trim. As these hogs were cut, the fat trim would include what normally is the unskinned backfat, clear-plate, cutting fat and ham trimmings. The fat cuts were also expressed as a percentage of the chilled weight.

Dressing percentage was computed with the shrunk live weights and the chilled carcass weights.

Weight per unit inch, and weight per unit inch divided by backfat (Aunan 1949) were also computed.

The formula (Dickerson 1946) -- $\text{Index} = (Yr) + (.04P + .4L + .2H - .5B - 1.5V)$ was used to compute the carcass score. In this formula:

Y - Yield of wholesale cuts in percentage of shrunk live weight (W).

r - relative price, based on the average of the Chicago weekly quotations for the five year period, 1937 to 1941 inclusive.

P - Ham plumpness index $\left(\frac{\text{Circumference}}{\text{length}} \times 100\right)$.

L - Loin eye muscle index (width X depth of eye muscle).

H - Ham muscle index (width X depth of lean on ham face).

B - Deviation of sum of the average backfat thickness from optimum -- $4.5 + \frac{(W-210)}{(40)}$.

V - Backfat range (difference between thickest and thinnest backfat measurement).

The relative values given the various cuts in this formula were: loin 1.0; ham .93; shoulder .80; belly .80; fat trim .35; and lean trim .53; (James 1948).

C. Determination of Specific Gravity:

Hydrostatic weighing, as described by Rathbun and Pace (1945) in their work with guinea pigs, was used to determine the carcass specific gravity on the 66 pork carcasses used in this study. Little difficulty was found in using this method on pork carcasses, except that in order to facilitate handling of the carcass and reduce the size of the tank needed, it was necessary to weigh the carcasses by halves.

Each half of the carcass was weighed in air to the nearest .1 pound then submerged in water and weighed to the nearest 5 grams. Care was taken that no air was trapped under the diaphragm muscle, in the flanks, or in jowl lest the carcass appear lighter than it really was. The weight in water was converted from grams to pounds to the nearest third decimal.

To weigh the carcass submerged in water a tank 6 feet deep and 8 feet in circumference was used. A 1500 gram capacity set of Torison balances were extended over the edge of a table placed across the opening for the elevator to the basement in the college meat laboratory. The tank was raised to floor level from the basement and filled with water. A heavy string attached to a small hook was suspended from the balances to the water level in the tank. Each side was suspended from the hook by the ham string into the water and the weight taken.

The weights of the entire carcass was computed from the sum of the weights of the two sides. The formula, (specific gravity = $\frac{\text{(wt. in air}}{\text{(wt. in air - wt. in water)}}$) was used to calculate the specific gravity.

D. Chemical Analysis:

The right side of all carcasses in Group II was analyzed chemically to determine the actual fatness of the carcasses. In order to salvage as much meat as possible the side was divided into four separates which were largely fat, lean, bone and skin. Each of the separates were analyzed for moisture, fat, protein and ash. The total composition of the side was computed from the sum of the analyses of the four separates.

The 5 gram samples taken for the chemical analyses came from a large sample (1/2 pint) which had been frozen to preserve the material from the time of cutting until chemical analysis could be made. The larger samples of each separate were taken by grinding the material coarsely, thoroughly mixing by hand and grinding coarsely again. The material was again thoroughly mixed and ground finely. As the finely ground material came from the mill it was sampled and placed in sealed containers to prevent any moisture loss during freezing and storage. Prior to taking the 5 gram samples the larger sample was thawed and thoroughly mixed.

For moisture determination approximately a 5 gram sample was weighed, dried for 12 hours at 105° C, and reweighed. The percentage weight loss was taken as percentage moisture in the separate. The residue from the moisture determination was ashed at a temperature of 625° C for 6 hours. The percentage residue from ashing was taken as the percentage ash in the separate.

For fat determination approximately a 5 gram sample was weighed, dried for 6 hours at 105° C, extracted with petroleum ether for 15 hours, dried again for 6 hours, and reweighed. The weight loss from the sample included both moisture and fat. The difference in the percentage of this weight loss and the percentage moisture loss in the first sample represented percentage fat in the sample. This percentage fat was taken as the percentage of fat in the separate. Nitrogen was determined on the residue from the fat determination by the Kjeldahl method. Protein was calculated as 6.25 times the total nitrogen content of the sample. The percentage protein of the sample was taken as the percentage protein in the separate.

E. Calculations:

The mean, range, standard deviation, and coefficient of variation was computed for each of the carcass measurements on both groups of carcasses. Simple correlations between the other carcass measurements and specific gravity, average backfat thickness, area of loin eye, percentage primal cuts, percentage lean cuts, and percentage fat cuts were calculated for each group. Sums of squares and crossproducts from the two groups were pooled to determine intra-group correlations. Partial correlations were used to remove the effect of variations in carcass weights on a number of the relationships. Multiple correlations were calculated to determine if a combination of the measurements had a higher predictive value than the individual measurements.

RESULTS

The means, ranges, standard deviations and coefficients of variation for the carcass measurements used in this study are presented for the two carcass groups in Table I. The standard deviations and coefficients of variability indicate that Group II carcasses were slightly more variable than the Group I carcasses in all measurements.

Table II presents the simple correlations of specific gravity, average backfat thickness, area of loin eye, percentage primal cuts, percentage lean cuts and percentage fat cuts with each other and with certain other carcass measurements. The correlations from Group I and Group II are combined by use of intra group correlations. In general, the correlations on Group II carcasses were slightly higher than the corresponding correlations on Group I carcasses. Intra group correlations of specific gravity with area of loin eye, percentage primal cuts, percentage lean cuts, carcass length, weight per unit inch divided by backfat, and carcass score were positive and highly significant. Highly significant and negative correlations were found between specific gravity and average backfat thickness, percentage fat cuts, chilled carcass weight, and weight per unit inch. The highest correlation of +.84 was between specific gravity and percentage lean cuts. Specific gravity generally yielded higher correlations than area of loin eye or average backfat with the various carcass measurements.

In Table III are presented correlations between the carcass measurements and chemical analyses on the right side of Group II carcasses. These correlations show that changes in specific gravity are more closely associated with the changes in ether extract and percentage protein than are either the changes in average backfat or area of loin eye. The percentage of fat cuts yielded a higher correlation with specific gravity than did the ether extract. Other correlations are generally similar to those in Table II.

Partial correlations were used to correct for the minor differences in carcass weight. The results are presented in Table IV. When compared to the simple correlations in Table II they show that differences in carcass weight as they existed in these data had little effect on the correlations of the various items.

Multiple correlations were calculated to see if a combination of some of the measurements would more accurately estimate fatness or leanness than would measurements of specific gravity alone. The results of these calculations, which are given in Table IV, indicate that the specific gravity of the carcass is as good a measure of fat or lean content as specific gravity used in combination with any of the measurements tried.

Specific gravities and chemical analyses for thirteen samples of boneless meat are presented in Table V. These were made in order to compare the specific gravities of the components of the pork carcass with those obtained for the guinea pig.

TABLE I

Means and Variation of Measurements Used

	Symbols	Group I $\bar{X}$	Group I Range	Group I s	Group I C	Group II $\bar{X}$	Group II Range	Group II s	Group II C
Shrunk wt.	W	214.4	208 -223	5.33	.0248	217.3	202 -230	6.25	.0288
Ave. backfat	BF	1.64	1.38 - 1.93	.15	.0909	2.00	1.41 - 2.62	.25	.1245
Area ham face	Ha	21.09	19.38 - 26.93	1.64	.0777	20.22	17.32 - 23.91	1.93	.0955
Area loin eye	La	5.59	4.34 - 7.31	.70	.1249	5.18	3.61 - 6.34	.71	.1378
Dressing %	D	71.9	68.2 - 74.4	1.20	.0171	71.9	68.6 - 74.6	1.5	.0212
Carcass length	L	29.02	27.50 - 30.30	.68	.0234	28.82	27.00 - 30.35	.74	.0256
Chilled wt.	w	154.6	145.1 -163.2	4.60	.0298	156.1	144.9 -164.2	5.51	.0353
Chilled wt. / length	w/L	5.33	4.89 - 5.75	.23	.0433	5.39	4.93 - 5.93	.25	.0456
Chilled wt. ÷ BF / length	w/L/BF	3.28	2.82 - 3.78	.24	.0716	2.74	2.21 - 3.50	.39	.1434
Carcass score	S	59.62	56.80 - 62.77	1.33	.0223	58.13	55.31 - 61.50	1.37	.0236
% Primal cuts	Pc	65.95	60.54 - 69.37	1.81	.0274	63.31	56.28 - 67.45	3.21	.0349
% lean cuts	Lc	48.40	44.71 - 51.67	1.24	.0256	45.24	38.78 - 50.40	2.53	.0559
% fat cuts	Fc	39.95	35.12 - 45.60	2.27	.0568	43.94	31.78 - 51.67	3.99	.0908
Specific gravity	Sg	1.027	1.012- 1.036	.006	.0057	1.026	1.013- 1.037	.007	.0072
On basis of total weight of right side:									
Ether extract	EE					54.56	44.77 - 64.06	4.10	.0751
% Moisture	M					31.82	24.80 - 40.15	3.06	.0962
% Protein	P					10.10	7.83 - 12.89	1.01	.1000
% Protein and Ash	PA					12.94	10.39 - 16.29	1.23	.0951
Fat free basis:									
% Moisture						70.05	66.58 - 72.72	1.49	.0275
% Protein						22.24	19.72 - 25.19	1.10	.0492
% Ash						6.28	4.13 - 7.21	.60	.0954

TABLE II

Correlations based on Measurements of the Entire Carcass

Symbols***		BF	La	Pc	Lc	Fc	Ha	L	W	W/L	W/L/BF	S	D
Sg	I	-.70**	+.32	+.57**	+.81**	-.71**	+.19	+.43*	-.59**	-.63**	+.48**	+.07	-.42**
	II	-.68**	+.60**	+.76**	+.87**	-.83**	+.25	+.66**	-.22	-.55**	+.42*	+.60**	-.07
Intra Group		-.68**	+.46**	+.68**	+.84**	-.78**	+.22	+.56**	-.42**	-.58**	+.43**	+.37**	-.17
BF	I		-.19	-.73**	-.66**	+.63**	-.10	-.60**	+.45*	+.46**	-.88**	+.10	+.35*
	II		-.48**	-.65**	-.74**	+.71**	-.53**	-.66**	+.34	+.64**	-.67**	-.36*	+.44*
Intra Group			-.37**	-.67**	-.72**	+.69**	-.38**	-.62**	+.38**	+.56**	-.73**	-.27*	+.39**
La	I			+.14	+.24	-.35*	+.37*	+.26	+.17	-.02	-.23	-.50**	+.23
	II			+.63**	+.71**	-.71**	+.67**	+.48**	+.16	-.14	+.35*	+.43*	+.04
Intra Group				+.41**	+.51**	-.47**	+.66**	+.37**	+.17	-.08	+.34**	+.46**	+.14
Pc	I				+.74**	-.48**	+.20	+.38*	-.42*	-.51**	+.61**	+.32	-.29
	II				+.90**	-.68**	+.56**	+.61**	-.19	-.50**	+.40*	+.73**	-.09
Intra Group					+.84**	-.60**	+.13	+.51**	-.29*	-.50**	+.47**	+.56**	-.19
Lc	I					-.72**	+.27	+.36*	-.54**	-.56**	+.50**	+.20	-.38*
	II					-.84**	+.67**	+.66**	-.24	-.56**	+.48**	+.64**	-.22
Intra Group						-.81**	+.52**	+.54**	-.35**	-.55**	+.48**	+.48**	-.28*
Fc	I						-.45**	-.42*	+.30	+.44*	-.53**	-.12	-.01
	II						-.74**	-.77**	-.01	+.41*	-.48**	-.52**	+.10
Intra Group							-.63**	-.61**	+.09	+.41**	-.50**	-.48**	+.05

* Significant at .05 level

** Significant at .01 level

*** These symbols are identified in Table I

TABLE III
Correlations of Carcass Measurements with Chemical Analysis on Right Side of Group II Carcasses

Symbols***	BF	La	Pc	Lc	Fc	EE	P	PA	M	Ha	L	w	w/L	w/L/BF
Sg	-.49**	+.68**	+.69**	+.78**	-.81**	-.75**	+.65**	+.72**	+.68**	+.43*	+.65**	.00	-.35*	+.57**
BF		-.54**	-.56**	-.70**	+.74**	+.48**	-.51**	-.58**	-.45**	-.50**	-.69**	+.30	+.61**	-.91**
La			+.20	+.78**	-.80**	-.60**	+.60**	+.64**	+.54**	+.64**	+.53**	+.35*	.00	+.64**
Pc				+.71**	-.72**	-.67**	+.59**	+.64**	+.60**	+.65**	+.57**	-.20	-.48**	+.44*
Lc					-.92**	-.67**	+.66**	+.77**	-.73**	+.85**	+.70**	-.28	-.48**	+.65**
Fc						+.78**	-.65**	-.78**	-.69**	-.57**	-.62**	+.22	+.51**	-.67**
EE							-.85**	-.87**	-.98**	-.44*	-.53**	.00	+.38*	-.45**
P								+.96**	+.76**	+.41*	+.61**	-.01	-.39*	+.49**
PA									+.52**	+.40*	+.62**	-.21	-.50**	+.51**

* Significant at .05 level
** Significant at .01 level
*** These symbols are identified in Table I

TABLE IV
Partial Correlations

Symbols*	Group I	Group II	Intra Group
Sg BF.w	-.589	-.664	-.619
Sg La.w	+.525	+.638	+.596
Sg Pc.w	+.438	+.753	+.644
Sg Lc.w	+.721	+.858	+.812
Sg Fc.w	-.746	-.857	-.822
BF La.w	-.303	-.589	-.360
BF Pc.w	-.606	-.632	-.629
BF Lc.w	-.554	-.717	-.678
BF Fc.w	+.580	+.753	+.717
La Pc.w	+.236	+.680	+.489
La Lc.w	+.398	+.781	+.620
La Fc.w	-.319	-.717	-.571

Multiple Correlations

Symbols*	Group I	Group II	Intra Group
Sg BF Fc			+.807
Sg BF Lc			+.862
Sg BF EE		+.759	
SG BF P		+.687	
Sg La EE		+.758	
Sg La P		+.682	

* These symbols are identified in Table I

TABLE V
Specific Gravity and Chemical Analysis of Boneless Meat

Sample No.	Kind of sample	Sp. Gr.	Ether Extract %	Protein %	Moisture %	Ash %
1	Skinned, bonelss ham	1.032	30.60	14.03	54.43	.61
2	"	1.034	26.69	15.47	57.23	.84
5	"	1.034	31.66	14.40	53.20	.75
6	"	1.044	21.70	16.22	60.70	.83
7	"	1.035	28.16	15.84	55.14	.73
8	"	1.035	29.39	15.28	54.66	.70
3	Skinned belly	.976	80,13	4.41	15.30	.18
4	"	.995	63.36	8.59	27.76	.37
11	"	.946	64.44	7.50	27.75	.37
12	"	.979	81.32	4.94	13.63	.23
9	Liver	1.075	1.22	20.62	71.93	1.45
10	"	1.069	2.35	19.68	72.96	1.74
13	Leaf fat	.948*				

* Chemical determinations were not made for this sample.

DISCUSSION

The specific gravity values obtained for the pork carcasses analyzed in this study do not appear to be in agreement with the values that have been determined for guinea pigs and man. The values found for the pork carcasses are lower and less variable. Whether the differences in experimental material would account for these discrepancies is not known. The data for the present study were obtained from immature animals in a relatively narrow weight range, whereas the data of Rathbun and Pace (1945) were taken from mature guinea pigs over a wide range in weights. Likewise, the data of Behnke et al. (1942) were taken from men over a wide range in weights. The amount of fat in the bodies of the men was not known, however the percentage fat in the guinea pigs was much lower than the percentage fat in the pork carcasses of this study. The data of Yapp (1923) were not considered comparable to the data in this study because it was not known whether correction had been made for gases in the lungs and intestines.

A comparison of the data presented in Table V with the specific gravity values given by Morales et al. (1945), shows differences which might be expected because of differences in fat content of the samples. The specific gravity of pure fat given for the guinea pig was .921 which is lower than the specific gravity (.948) found for leaf fat in this study. The higher specific gravity of leaf fat might be due to the small amount of protein and ash present as connective tissue. Chemical determinations were not made for the leaf fat. Lange, (1941) gives the specific gravity of pure pork fat as .938. The samples of boneless ham were predominantly lean, yet the specific gravity values for these samples were much lower than the value given by Morales et al. for fat-free muscle, 1.066. It will be noted however, that there was approximately 30 percent fat in the samples of boneless ham which would reduce the specific gravity of these samples. This illustrates the value of specific gravity for estimating the amount of intramuscularfat in the carcass. The specific gravity of the samples of skinned belly is slightly higher than the specific gravity of the leaf fat. This is to be expected since there was a small streak of lean in these samples of belly.

From Table I it is apparent that there is greater variation in the carcass measurements of Group II than in Group I. This greater variation in Group II carcass measurements may be attributed to three factors: (1) Group II carcasses were more variable in weight; (2) they were more variable in fat content and (3) they were slightly fatter than the carcasses of Group I.

With the exception of area of loin eye, the measures of leanness or muscling show smaller coefficients of variation than do the measures of fatness. These findings are in agreement with Dickerson (1947) and indicate that the fat content of the carcass is more variable than the lean or bone content. Probably the irregular shape of the loin eye muscle caused errors in measurement which were multiplied in the calculation of the area, thus causing the large coefficient of variability in this measurement. The relatively greater variability in fat content is further shown when the composition of the right side of Group II carcasses is computed on a fat free basis. When calculated on a fat free basis the variability in the percentage moisture was reduced by 71 percent and the variability in the percentage protein was reduced by 51 percent. This reduced variability of the moisture and protein, after accounting for variations in fat, tends to support the idea of a relatively constant lean body mass in the mature animal, which has been suggested by Mitchell and Hamilton (1929) and Rathbun and Pace (1945). The establishment of a relatively constant lean body mass in the mature animal would mean that the gross composition of the mature animal carcass could be computed from the determination of the fat content of the carcass. It is realized that most of our slaughter animals are not mature. However, animals of approximately the same age and weight should have a comparable lean body mass, thus making it possible to estimate the gross composition of the carcasses of our slaughter animals from a measure of fatness.

Table II shows that in most cases the correlation coefficients on Group II carcass measurements were higher than the correlation coefficients on Group I carcass measurements. These differences were thought to be due to the greater variation of the carcasses in Group II. Intra group correlations between specific gravity and area of loin eye, percentage primal cuts, percentage lean cuts, carcass length, weight per unit inch divided by average backfat and carcass score were positive and highly significant. Highly significant and negative correlations were found between specific gravity and average backfat, percentage fat cuts, carcass weight and weight per unit inch.

The correlations between specific gravity and the above measurements were higher than between these measurements and average backfat or area of loin eye for example percentage lean cuts when correlated with specific gravity, average backfat thickness, and area of loin eye gave coefficients of +.84, -.72, and +.54 respectively. Coefficients of determination indicate that changes in specific gravity are associated with 71 percent of the variation in lean cuts. This means that if specific gravity were held constant then 71 percent of the variation in percentage lean cuts would disappear. On the other hand average backfat thickness and area of loin eye are associated with only 52 and 29 percent respectively, of the variation in percentage of lean cuts. This same trend is noted in the correlations between percentage fat cuts and specific gravity, average backfat thickness, and area of loin eye. The coefficients of of determination indicate a definite advantage in the use of specific gravity for estimating lean cuts or fat cuts on the intact carcass as compared to using the average backfat thickness of area of loin eye.

Winters and Aunan (1949) suggest that the factor, weight per unit inch divided by average backfat thickness, may be used to estimate the fatness or leanness of the intact carcass with considerable accuracy. In the present study this factor was highly correlated with percentage fat cuts and percentage lean cuts. However, these correlations were not as high as were the correlations of specific gravity with percentage fat cuts or percentage lean cuts. In this study weight per unit inch divided by average backfat thickness was not correlated as highly with the various measures of fatness or leanness as was average backfat alone.

With the exception of average backfat thickness there was little correlation between dressing percentage and the carcass measurements. This suggests the possible over emphasis of the importance of dressing percentage in determining carcass merit.

Table III presents correlations between the carcass measurements and chemical analyses of the right side of Group II carcasses. The correlations of items on the right side are not as high as the correlations of items on the entire carcass. This might be expected when variations in splitting the carcass are considered.

Table III showed generally higher correlations between specific gravity and the measurements studied than between average backfat thickness and those measurements. There is little difference in the correlations of specific gravity or area of loin eye with these measurements. It was noted above that specific gravity yielded higher correlations with the various measurements from both sides than did area of loin eye. Therefore, it appears that error was introduced when the area of loin eye from one side of the carcass was applied to the entire carcass as a measure of leanness.

Percentage protein when correlated with specific gravity and percentage lean cuts gave coefficients of +.65 and +.66 respectively. However, the correlation between specific gravity and percentage lean cuts was +.78. Calculation of coefficients of determination show that changes in specific gravity are 20 percent more closely associated with changes in percentage of lean cuts than with changes in percentage of protein. A similar situation is noted in the correlations between specific gravity, percentage fat cuts and ether extract. Specific gravity was more closely associated with percentage fat cuts than with ether extract.

It is possible that errors in the chemical determinations account for the fact that the percentage protein was less closely associated with the percentage of lean cuts than was the specific gravity, and that ether extract was less closely associated with the percentage of fat cuts than was specific gravity. The principle difficulty in chemical analysis is in obtaining a representative sample of the carcass for analysis. It is recognized that no sampling is free from error, but the sources of error encountered in sampling the carcasses of this study are rather characteristic of sampling large quantities of biological material. The personal, and instrumental error involved in the sampling was thought to be small and insignificant since the same personell and the same equipment were used for all samples. The difficulty in adequately mixing the large quantity of material being handled was thought to contribute considerably to sampling error. This difficulty was due partly to the amount of material and partly to a loss of liquid fat from the material if ground too finely. The loss of moisture due to evaporation during the cutting and sampling process was also a source of an undetermined amount of error which would contribute to the error in sampling. These sources of error were probably responsible for the correlations between the chemical composition and the various measurements in this study being lower than was expected.

Warner et al. (1934) ranked the methods of determining the actual fatness of the pork carcass in order of their probable accuracy as follows: (1) chemical analysis of the entire carcass; (2) the chemical analysis of some single representative cut; (3) the weight of the particularly fat or lean cuts in relation to the weight of the entire carcass and; (4) measurements of parts of the carcass, especially the fat portions such as the thickness of the fat on the ham, shoulder and back.

Scott (1929) showed that variation in cutting was not significant when comparisons were between groups containing more than four carcasses.

Considering the number of hogs used in the present study along with the sampling errors involved in the chemical analyses, it appears that the actual leanness or fatness in the pork carcass was as accurately estimated from the percentage fat cuts or percentage lean cuts as from chemical determinations. Analysis of the data presented in this study indicates that there is little difference in the relationship of specific gravity, percentage fat cuts, or percentage lean cuts to the other criteria used to indicate fatness or leanness in the carcass. If this is true, specific gravity could be used to estimate the fat content of the carcass as accurately as could the percentage fat cuts and would have the advantage of providing the same information before the carcass is cut.

This study shows a high relationship between the specific gravity and the fat or lean content of the carcass. Further study to determine the range of application for estimates of fatness or leanness by the methods suggested here seem necessary.

SUMMARY AND CONCLUSIONS

Carcass data from two groups of hogs were studied, to investigate the possibility of using specific gravity as a means of estimating the fat or lean content of the carcass. Group I included 34 hogs from 3 inbred Duroc lines and their crosses produced in the Oklahoma Swine Breeding Project. Group II included 32 individually fed outbred Duroc hogs used in a feeding trial at the Oklahoma Station. Hogs from both groups were slaughtered at weights ranging from 202 to 230 pounds.

The average specific gravity for the 66 carcasses was 1.027.

Intra-group correlations of specific gravity with area of loin eye, percentage primal cuts, percentage lean cuts, carcass length, weight per unit inch divided by backfat, and carcass score were positive and highly significant. Highly significant and negative correlations were found between specific gravity and average backfat thickness, percentage fat cuts, chilled carcass weight, and weight per unit inch.

The correlations calculated in this study indicate that the fat or lean content of the carcass may be as accurately estimated by the specific gravity as by the percentage fat cuts or percentage lean cuts.

Partial correlations indicated that differences in carcass weights had little effect on correlations between the various items measured.

Multiple correlations indicated that specific gravity combined with some of the better measures of fatness or leanness was no more closely related to fat or lean content of the carcass than was specific gravity alone.

From this study it appears that there is a high relationship between the specific gravity, the fat content, and the lean content of the carcass. Therefore, the use of specific gravity to estimate the fat or lean content of the carcass is possible and would be a simple and practical means of measuring fat or lean content of the carcass before cutting.

LITERATURE CITED

Aunan, W. J. and L. M. Winters. 1949. A Study of the Variations, of Muscle, Fat, and Bone of Swine Carcasses. Jour. Ani. Sci. 8:182-190.

Behnke, A. R., B. G. Feen, and W. C. Welham. 1942. The Specific Gravity of Healthy Men. Jour. Am. Med. Assoc. 118:495-206,

Behnke, A. R. and W. C. Welham. 1942. The Specific Gravity of Healthy Men. Jour. Am. Med. Assoc. 118:207-214.

Boyd, Edith. 1933. The Specific Gravity of the Human Body. Human Biology. 5:656-672.

Dickerson, G. E. 1946. Comments on Carcass Study. Record of Proc. Conf. and Collaborators Reg. Swine Breeding Lab. pp 14-15.

Dickerson, G. E. 1947. Composition of Hog Carcasses as Influenced by Heritable Differences, in Rate and Economy of Gain. Iowa Res. Bul. 354.

Dickerson, G. E., B. R. McClurg, and F. J. Beard. 1943. The Relation Between Carcass Conformation and the Value of the Live Hog. Jour. Ani. Sci. 2:373-374.

Hankins, O. G. 1940. A Study of Carcass Characteristics in Relation to Type of Hog. Amer. Soc. Ani. Prod., Proc. pp 284-289.

Hankins, O. G. and N. R. Ellis. 1934. Physical Characteristics of Hog Carcasses as Measures of Fatness. Jour. Agri. Res. 48:257-264.

Hazel, L. H., C. P. Reinmiller, and H. L. Baker. 1943. The Relationship Between Growth Rate and Carcass Measurement in Swine. Jour. Ani. Sci. 2:375-376.

Hiner, R. L. and O. G. Hankins. 1939. Significance of Variation in Ham Conformation. Jour. Agri. Res. 59:293-302.

James, W. L. 1948. A Comparison of Carcasses of Pigs from Different Lines of Breeding. Master's Thesis, Oklahoma A. and M. College.

Lange, N. A. 1941. Handbook of Chemistry. Sandusky, Ohio: Handbook Publishers Inc. 4th Ed.

Loeffel, W. J., W. W. Derrick, and M. Peters. 1943. Weight of Pigs as it Affects Gains and Carcass Qualities. Nebr. Exp. Sta. Bul. 351.

McMeekan, C. P. 1940. Growth and Development in the Pig, with Special Reference to Carcass Quality Characters. Jour. Agri. Sci. 30:276-344.

McMeekan, C. P. 1941. The Use of Sample Joints and of Carcass Measurements of Indices of Composition of the Bacon Pig. Jour. Agri. Sci. 31:1-17.

Mitchell, H. H. and T. S. Hamilton. 1929. The Energy and Protein Requirements of Growing Swine and the Utilization of Feed Energy in Growth. Ill. Exp. Sta. Bul. 323.

Morales, M. F., E. N. Rathbun, R. E. Smith and N. Pace. 1945. Theoretical considerations Regarding the Major Body Tissue Components with Suggestions for Application to Man. Jour. Biol. Chem. 158:677-684.

Pace, N. and E. N. Rathbun. 1945. The Body Water and Chemically Combined Nitrogen Content in Relation to Fat Content. Jour. Biol. Chem. 158:685-691.

Rathbun, E. N., and N. Pace. 1945. Determination of Total Body Fat by Means of Body Specific Gravity. Jour. Biol. Chem. 158:667-676.

Scott, E. L. 1930. The Influence of the Growth and Fattening Processes on the Quantity and Quality of Meat Yielded by Swine. Ind. Expt. Sta. Bul. 340.

Snedecor, G. W. 1946. Statistical Methods Applied to Experiments in Agriculture and Biology. Ames, Iowa: Iowa State College Press. 4th Ed.

Warner, K. F., N. R. Ellis, and P. E. Howe. 1934. Cutting Yields of Hogs as and Index of Fatness. Jour. Agri. Res. 48:241-255.

Willman, J. P. and J. L. Krider. 1943. A Study of the Characteristics of Live Market Hogs as Related to the Quality of Carcasses Produced. Jour. Ani. Sci. 2:231-236.

Winters, L. M., C. F. Sierk, and J. N. Cummings. 1949. The Effect of Plane of Nutrition on the Economy of Production and Carcass Quality in Swine. Jour. Ani. Sci. 8:132-140.

Yapp, W. W. 1923. A Dimension - Weight Index for Cattle. Amer. Soc. Ani. Prod., Proc. pp 50-56.

Zook, D. E. The Physical Growth of Boys. 1929. Amer. Jour. of Diseased Children. 43:1347-1432.

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