PHYSICAL CHARACTERISTICS OF HOG CARCASSES AS MEASURES OF FATNESS[1]

O. G. HANKINS, *senior animal husbandman*, and N. R. ELLIS, *chemist, Animal Husbandry Division, Bureau of Animal Industry, United States Department of Agriculture*[2]

INTRODUCTION

The fatness of meat animals and carcasses, known also as "finish", is a characteristic of great practical importance. In animals intended for slaughter, fatness merits consideration with respect to both the growing of meat animals and the requirements of consumers. The fattening of an animal is relatively expensive in contrast with producing earlier growth. Normally the consumption of feed per unit of gain during fattening is greater than during the growth period, when the increase in weight consists largely of bone and muscle tissue. The longer the fattening is continued the more costly the gains become.

Within a reasonable limit, increased finish is believed by many to be associated with increased desirability of meat from the consumer's standpoint. However, the exact degree of finish associated with the most desirable quality of the different classes of meat and the specific manner in which the fat influences palatability are yet to be determined. From these considerations it is clear that a simple means of measuring fatness, besides being of practical importance, should facilitate technical studies relating to livestock production and the characteristics of meat and meat food products.

In view of the foregoing it is apparent that an essential phase of studies dealing with the quality of meat is the determination, or at least a reliable estimation, of the proportion of fat in the individual carcass. Accurate interpretation of results is difficult, if not impossible, without information of this nature. Existing methods for measuring the fatness of hog carcasses may be criticized either as lacking in exactness or as being relatively expensive in time or material.

Any advance in methods for making estimates of fatness is of interest and value to research workers. If the improved method is one which can be applied quickly with little expense, it may have direct value from certain practical points of view.

Experiments conducted as a part of the national project, cooperative meat investigations, have taken carcass composition extensively into account. This has been true particularly in the beef and pork studies. In connection with this work many physical and chemical analyses of beef and pork carcasses and their respective cuts have been made by the Animal Husbandry Division of the United States Department of Agriculture. The ninth–tenth–eleventh rib cut from

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the right side was adopted as the standard beef-carcass sample by the cooperators in the national project, and it has been used to indicate the composition of the dressed carcass as a whole. Through the analyses of a large number of pork carcasses and their respective cuts the Division established the fact [3] that the trimmed ham is a satisfactory sample from which the fatness of the carcass may be estimated. This greatly simplifies the work of physical and chemical analyses of the fat content of hog carcasses.

Cutting yields have been found by Warner, Ellis, and Howe [4] to be a valuable method for estimating fatness. The correlation between the sum of the percentages of trimmed belly, leaf fat, back fat, and fat trimmings, and the percentage of ether extract in the total edible portion of the carcass was $+0.91 \pm 0.02$ for a total of 75 hogs.

In employing this method of estimating fatness, the carcass, of course, must be cut by a certain standard method and the various cuts weighed. The present paper gives a method which is applicable to the uncut carcass and thus has a somewhat different field of usefulness.

METHODS AND MATERIALS

For several years the Animal Husbandry Division has been interested in the possibilities offered by carcass measurements in connection with meat studies. These included, among other considerations, their possible usefulness in estimating fatness.

In 1929 a set of 15 measurements was developed for use on hog carcasses.[5] This method is applicable to center-split carcasses. A steel tape is used for taking all measurements except nos. 1, 13, and 14. All measurements are taken in millimeters, with the carcass hanging from a hook in the normal position, head down.

METHOD OF MEASURING CARCASSES

Length

(1) Head: From the snout, between nostrils, to the tip of the atlas joint (occipito-atloid articulation). (Calipers.)

(2) Neck: From the base of the atlas joint to the anterior aspect of the first dorsal vertebra.

(3) Body: From the anterior edge of the first rib to the lowest point (as the carcass hangs on the hook) of the aitch bone.

(4) Hind leg: From the lowest point of aitch bone to the coronary band of the foot.

Depth at Seventh Dorsal Vertebra

(5) Thickness of back fat, exclusive of skin.[6]

(6) Distance from the lower margin of the back fat to the upper edge of the spinal canal.

(7) Distance from the upper edge of the spinal canal to the lower edge of the split breastbone.

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[3] Unpublished data.

[4] Warner, K. F., Ellis, N. R., and Howe, P. E. Cutting yields of hogs an index of fatness. Jour. Agr. Research 48: 241-255, illus.

[5] This method of measuring hog carcasses, except the steps relating to thickness of back fat, was developed by a committee consisting of O. G. Hankins, H. C. McPhee, and K. F. Warner, of the Animal Husbandry Division. The back-fat measurements had been employed since 1927 by N. R. Ellis, W. O. Pool (resigned), and R. M. Riemenschneider in studies on the relationships between certain production factors and thickness of back fat, and between the latter and firmness as determined by laboratory tests and committee judgment.

[6] Also included with (8), (9), (10), and (11) as one of the 5 measurements of thickness of back fat.

THICKNESS OF BACK FAT

(8) At the first dorsal vertebra.
(9) At point 7 vertebrae below last lumbar. (Include last lumbar vertebra in count.)
(10) At point 3½ vertebrae below last lumbar. (Include last lumbar vertebra in count.)
(11) At last lumbar vertebra.

CIRCUMFERENCE OF FRONT LEG

(12) Right front leg: At point of least circumference between knee and pastern joints.

WIDTH AND PLUMPNESS

(13) Shoulder: Width from inside of carcass at first dorsal vertebra to outside of shoulder on a line parallel to the floor. Sum of measurements of both sides of carcass is recorded. (Calipers.)
(14) Ham: Width from top point of the aitch bone to the outside of the ham on a line parallel to the floor. Sum of measurements of both sides of carcass is recorded. (Calipers.)
(15) Ham plumpness: (*a*) Length from lowest point of aitch bone to center of inside of hock joint located at bony projection which may be felt under the skin; (*b*) circumference at mid point of measurement (*a*), obtained by locating 3 or 4 points on ham equidistant from plane through center of hock joint, such points marked with sharp metal skewers and ham encircled with steel tape immediately below skewers for measurement; (*c*) measurement (*b*) multiplied by 100 and divided by measurement (*a*) gives index of plumpness.

Measurements 5, 8, 9, 10, and 11 are averaged to give the "average thickness of back fat." Detailed consideration is given later to this carcass characteristic.

Since 1929 the foregoing method has been applied to a large number of individual hogs. The carcasses measured were those of animals used in a number of cooperative and independent experiments of varied nature and objectives. Some of the experiments involved chemical analyses of entire carcasses exclusive of bone and skin. Thus data were obtained from which it was possible to determine the relationships between certain selected measurements and the fatness of the edible portion of the carcasses. The purpose of this paper is to report on the relationships found.

Sixty hogs were used in five experiments. Two of the experiments were conducted cooperatively by the North Carolina Agricultural Experiment Station and the United States Department of Agriculture. The others were conducted independently by the Department. The hogs in these experiments varied with respect to age, breed, sex, type, and initial weight, kind and quantity of feed, rate of gain, total gain, final weight, and market grade. The range of final feed-lot weights, for example, was from 93 to 250 pounds. Some of the hogs were fed such a limited ration during part of the experiment as to result in a material loss in weight after they had reached a weight of approximately 225 pounds. The large number of these variables and the extent of the variability in certain instances are believed to add significance to the results of the special study on fatness.

The thickness of back fat is usually observed in forming an opinion on the fatness of a hog carcass and is generally regarded as a dependable, practical guide. As previously explained, the thickness of back fat was measured at five different points, in the work reported herein, and these five measurements on each carcass were averaged, the figure so obtained being designated the "average thickness of back

fat." These average values for the 60 hogs were correlated with the percentages of fat (ether extract) in the total edible portion of the carcasses.

RELATION BETWEEN THICKNESS OF BACK FAT AND PERCENTAGE OF FAT IN EDIBLE PORTION OF CARCASS

Figure 1 is a scatter diagram showing the relationship between the average thickness of back fat in millimeters and the percentage of fat in the total edible portion of the carcass, for the 60 hogs analyzed. The regression line and its standard error are also shown.

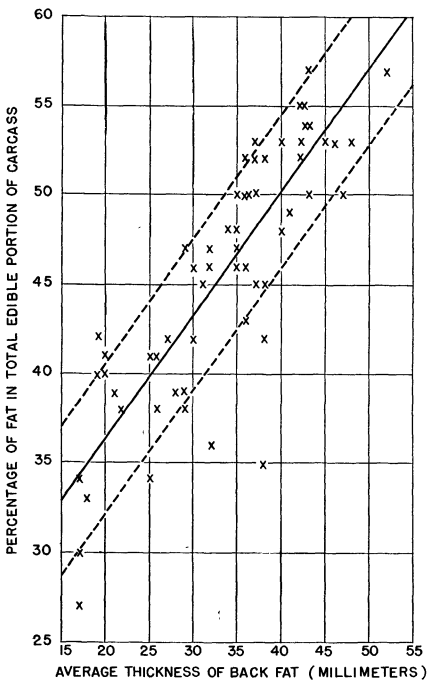

FIGURE 1.—Relation between average thickness of back fat and percentage of fat in edible portion of hog carcass. Each symbol (×) represents 1 of 60 hogs varying in type.

The equation for the regression line, of the form $y = a + bx$, is as follows:

Percentage of fat in total edible portion of carcass = 22.45 + 0.691 × average thickness of back fat.

It appears from figure 1 that the relationship is linear or that the straight line fits the points on the diagram in a satisfactory manner. It does not necessarily hold, however, that this relationship would apply to hogs having back fat less than about 15 mm in thickness, in which case the trend would obviously be downward. The standard error of the regression line or of the percentage of fat in the edible portion of the carcass is 4.2.

The correlation coefficient representing the relationship between the two characteristics under consideration was found to be +0.84 with a standard error of ±0.04. The corresponding coefficient of determination is 0.71. The relationship, represented by the coefficient +0.84, was the closest found between fatness and any of the other physical characteristics of the carcasses included in the study of the 60 hogs as one group.

It is of interest in this connection that the correlation between the chemically determined fat content of the edible portion of the carcasses and of the trimmed, right hams, the latter being the standard carcass sample for analysis, was +0.93 ± 0.02. A comparison of the square (0.86) of this coefficient with 0.71, mentioned above, indicates that slightly greater accuracy is gained by analyzing the ham, instead of measuring the thickness of back fat to obtain an estimate of the fatness of the carcass. Conversely, the comparison indicates the accuracy sacrificed by employing the more rapid, less expensive method which may be applied as the split carcasses hang on the rail.

In the study by Warner, Ellis, and Howe[7] the sum of the percentages of trimmed belly, leaf fat, back fat, and fat trimming, and the percentage of fat in the total edible portion of the hog carcass showed a relationship represented by the correlation coefficient $+0.91 \pm 0.02$. The standard error of the regression line or in the percentage of carcass fat as estimated by this cutting-yield method was ± 3.3. It is apparent from these results that the average thickness of back fat is a hog-carcass characteristic of very definite value for estimating the fatness of the edible portion of the carcass as a whole.

TYPE OF HOG IN RELATION TO VALUE OF THE METHOD

With a few exceptions the type as shown by the individual hogs just prior to slaughter was judged and recorded by a committee of three members of the Department staff.[8] Three major types were recognized, viz, large, intermediate, and small. Thirty-four of the hogs were classed as intermediate in type. This relatively large number of one type afforded an opportunity to throw light on the question whether average thickness of back fat is a more useful index of fatness when type is uniform than when it varies.

Figure 2 shows the relationship between the two factors among the 34 intermediate-type hogs.

The equation for the regression line representing the 34 hogs is as follows:

Percentage of fat in total edible portion of carcass = $25.16 + 0.621 \times$ average thickness of back fat.

The standard error of the regression line is ± 3.5. This may be compared with ± 4.2 when all 60 hogs are considered. By assuming an infinite number of hogs in both cases and adjusting the standard errors of the regression lines accordingly, the difference between the standard errors was found to remain practically the same. The smaller standard error of the regression line for the 34 hogs suggests that uniformity in type was a factor resulting in slightly greater accuracy in the estimation of percentage of fat in the edible portion of the carcass from the average thickness of back fat. However,

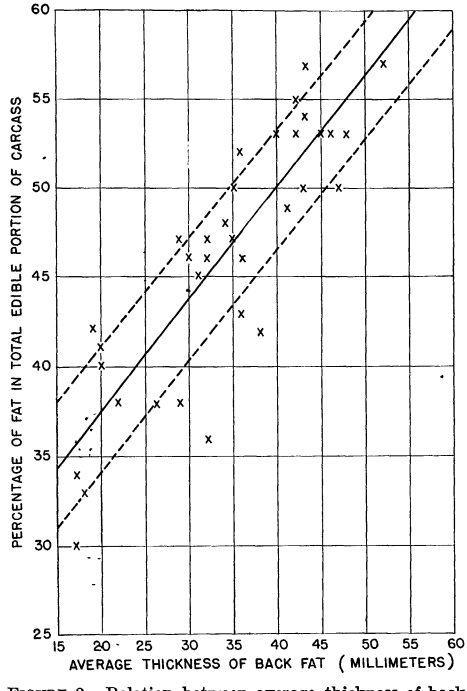

FIGURE 2.—Relation between average thickness of back fat and percentage of fat in edible portion of hog carcass. Each symbol (×) represents 1 of 34 hogs of intermediate type.

[7] WARNER, K. F., ELLIS, N. R., and HOWE, P. E. See footnote 4.

[8] Two members of this committee were representatives of the Bureau of Animal Industry, and one of the Bureau of Agricultural Economics.

the corresponding correlation coefficients were $+0.87 \pm 0.04$ and $+0.84 \pm 0.04$, and the difference between the two is not statistically significant.

Table shows the average calculated percentages of fat in the edible portion of the carcass which correspond to different thicknesses of back fat. It was prepared by using the regression equation given above.

TABLE 1.—*Average calculated percentages of fat in edible portion of hog carcasses as related to different thicknesses of back fat*

[Average of 5 measurements in each case]

Thickness of back fat (millimeters)	Fat in edible portion of carcasses of—		Thickness of back fat (millimeters)	Fat in edible portion of carcasses of—		Thickness of back fat (millimeters)	Fat in edible portion of carcasses of—	
	Hogs varying in type	Hogs intermediate in type		Hogs varying in type	Hogs intermediate in type		Hogs varying in type	Hogs intermediate in type
	Percent	*Percent*		*Percent*	*Percent*		*Percent*	*Percent*
10	29.4	31.4	25	39.7	40.7	40	50.1	50.0
15	32.8	34.5	30	43.2	43.8	45	53.5	53.1
20	36.3	37.6	35	46.6	46.9	50	57.0	56.2

Table 1 shows that at a back-fat thickness of 40 mm the difference in fatness between the two groups of hogs was least.

OTHER FACTORS CONSIDERED IN RELATION TO FATNESS

A number of other measurements, in addition to average thickness of back fat, were studied to determine their values as indices of fatness or of the percentage of fat in the total edible portion of the carcass. Certain ratios, final feed-lot weight, and chilled-carcass weight were also considered. The relationships found are shown below in decreasing order of magnitude, expressed as coefficients of correlation. The standard error of the coefficient is also shown in each instance.

(1) Thickness of back fat at seventh dorsal vertebra (measurement 5) $+0.77 \pm 0.05$
(2) Width through shoulders (measurement 13) $+ .74 \pm .06$
(3) Weight of chilled carcass divided by total length of body and leg (sum of measurements 3 and 4) $+ .73 \pm .06$
(4) Thickness of back fat at seventh dorsal vertebra (measurement 5) divided by depth of carcass exclusive of back fat (sum of measurements 6 and 7) $+ .72 \pm .06$
(5) Weight, final feed-lot $+ .67 \pm .07$
(6) Weight of chilled carcass $+ .67 \pm .07$
(7) Depth of carcass (sum of measurements 5, 6, and 7) divided by length of leg (measurement 4) $+ .65 \pm .07$
(8) Width through hams (measurement 14) $+ .63 \pm .08$
(9) Plumpness of ham (measurement 15) $+ .59 \pm .08$
(10) Length of body (measurement 3) divided by mean of widths through shoulders and hams (measurements 13 and 14) $- .58 \pm .09$
(11) Depth of carcass (sum of measurements 5, 6, and 7) $+ .56 \pm .09$
(12) Length of body (measurement 3) divided by depth of carcass (sum of measurements 5, 6, and 7) $- .54 \pm .09$
(13) Length of body (measurement 3) $+ .40 \pm .11$
(14) Depth of loin (measurement 6) $+ .39 \pm .11$
(15) Entire length (sum of measurements 1, 2, 3, and 4) $+ .35 \pm .11$
(16) Length of ham (measurement 15) $+ .33 \pm .12$

Consideration of these 16 correlation coefficients is simplified by classifying them into four groups. Group 1 includes those which involve direct measurement of the layer of external fat or coefficients

(1, 2, and 8). There is little difference between the thickness of back fat at the seventh dorsal vertebra and the width of carcass through the shoulders as indices of percentage of fat in the total edible portion of the carcass. However, width through the hams is represented by a considerably lower value.

Group 2 includes all coefficients which involve a ratio as one of the correlated factors. These are the relationships designated above as 3, 4, 7, 9, 10, and 12. The first-mentioned and highest, in which weight per unit of length is considered in relation to fatness, is a moderately high value ($+0.73 \pm 0.06$). The second is practically identical with it. Relationship 9 indicates that increasing plumpness of ham is not necessarily closely accompanied by increasing fatness of carcass. This suggests, in turn, that a high degree of plumpness may be due largely, in some cases, to unusual muscular development without a thick covering of fat. Relationships 10 and 12, the two lowest in this group, are interesting on account of the small difference between them. It is obvious that it made little difference whether the average of the widths of carcass through the shoulders and hams or the depth of carcass was involved in the ratio.

Group 3 consists of the relationships which involve weight as one of the correlated factors. The two such relationships included are those involving (1) final feed-lot weight (5), and (2) chilled-carcass weight (6). The correlation coefficients and standard errors in the two cases are identical ($+0.67 \pm 0.07$). The corresponding coefficient of determination, 0.45, indicates that slightly less than 50 percent of the variation in fat content of the edible portion of the carcass is associated with weight alone, when the latter is regarded as an independent factor.

Direct measurements of depth and length are involved in the relationships included in group 4 and designated 11, 13, 14, 15, and 16. All these coefficients are so low that the measurements are of little interest or significance in relation to the fatness of the carcass. In this connection, the relative values of depth of carcass (11), width through shoulders (2), and width through hams (8) are of special interest. Width through shoulders ($+0.74 \pm 0.06$) was distinctly superior to either of the others as an index of fatness, whereas width through hams showed only a slightly higher correlation than depth of carcass with percentage of fat in the edible portion of the carcass ($+0.63 \pm 0.08$ in comparison with $+0.56 \pm 0.09$).

SUMMARY

The method of measuring hog carcasses presented in this paper has been applied since 1929 to a large number of carcasses. The composition of 60 of these measured carcasses was determined by chemical analysis. Data were obtained from which it was possible to determine the relationships between certain measurements and the fat content of the edible portion of the carcasses.

The 60 measured and analyzed carcasses were those of hogs used in two cooperative experiments with the North Carolina Agricultural Experiment Station and three independent experiments. The experiments varied in nature and primary objectives. The hogs varied with respect to age, breed, sex, type, and initial weight, kind and quantity of feed, rate of gain, total gain, final weight, and market grade. Some were even fed to gain and then lose weight during the period of the experiment.

The thickness of back fat is generally regarded as a dependable, practical indication of the fatness of a hog carcass. It was measured on each carcass at five specific points, and the five measurements were averaged to obtain a value for average thickness of back fat. These average values were correlated with the percentages of fat, or ether extract, in the edible portion of the 60 carcasses. A correlation coefficient of $+0.84$ was obtained, the standard error of the coefficient being ± 0.04. The equation derived for the regression line representing the relationship was percentage of fat in total edible portion of carcass $= 22.45 + 0.691 \times$ average thickness of back fat.

The accuracy sacrificed by employing this rapid, inexpensive method for estimating fatness is indicated by comparing its correlation coefficient with (1) the coefficient representing the relationship between the chemically determined fat content of the edible portion of the carcasses and that of the trimmed right hams and (2) the coefficient representing the relationship between the fat content of the carcasses and the sum of the percentages of trimmed belly, leaf fat, back fat, and fat trimmings. The three correlation coefficients are 0.84 ± 0.04, $+0.93 \pm 0.02$, and 0.91 ± 0.02, respectively. The coefficients of determination for the three methods of estimating fatness are 0.71, 0.86, and 0.83, respectively. The standard errors of the regression lines for the three methods are ± 4.2, ± 1.7, and ± 3.3, respectively. The results show that, for representative animals, the average thickness of back fat is a hog-carcass characteristic of very definite value for estimating fatness of the edible portion of the carcass.

Separate consideration was given to 34 of the hogs, which were classed intermediate in type. A smaller standard error of the regression line for this group suggests that uniformity in type was a factor resulting in slightly greater accuracy in the estimation of fatness in the edible portion from the average thickness of back fat. However, the difference between the correlation coefficients for the two groups was not statistically significant.

A number of other measurements, also certain ratios, final feed-lot weight, and chilled-carcass weight were studied to determine their values as indices of the percentage of fat in the total edible portion of the hog carcass.

The 16 factors are classified into 4 groups. Group 1 includes those that involved direct measurement of the layer of external fat; group 2, those which appear as ratios; group 3, final feed-lot weight and chilled-carcass weight; and group 4, those appearing as direct measurements of depth and length.

Of the 6 highest correlation coefficients among the total of 16, the 2 highest values are in group 1, the next 2 in group 2, and the lowest 2 in group 3. Thickness of back fat at the seventh dorsal vertebra gave the highest coefficient ($+0.77 \pm 0.05$), width through shoulders being a close second. Weight per unit length of body plus leg and thickness of back fat at the seventh dorsal vertebra divided by depth of carcass (exclusive of back fat) gave coefficients only slightly lower than the latter.

Final feed-lot weight and chilled-carcass weight gave identical coefficients, too low to be of particular interest. Likewise, all group 4 factors showed little relation to the fatness of the carcass.