Objective Grade Specifications for Slaughter Barrow and Gilt Carcasses

by Owen L. Brough and Geoffrey Shepherd

Department of Economics and Sociology

AGRICULTURAL EXPERIMENT STATION, IOWA STATE COLLEGE

RESEARCH BULLETIN 421 JANUARY, 1955 AMES, IOWA

CONTENTS

SUMMARY

Hogs are usually sold in the United States on a liveweight basis. Official federal grade standards for hogs were not established until 1952.

The purpose of this study was to attempt to develop objective carcass grade specifications for slaughter barrows and gilts. These grade specifications should have economic significance and at the same time should be practical and acceptable to the hog industry.

Detailed carcass measurements were made of 600 hog carcasses at the Iowa Packing Company, Des Moines, Iowa. Each carcass then was subjected to a detailed cutout test to determine the weight and quality grade of the various component wholesale cuts and trimmings. The ratio of the weights of the four high-value lean cuts (hams, loins, picnics and boston butts) to the total carcass weight was computed for each carcass. This ratio (called the index of lean) is a measure of the relative values of the hog carcasses. The higher the index of lean, the higher the value of the carcass, until the point is reached where the carcasses are discounted for lack of quality. Thus, for any schedule of prices for the various wholesale cuts and trimmings there is an optimum index of lean which will yield the highest carcass value.

The objective measurements, backfat thickness, carcass length and carcass weight used in this study were found to be correlated with the index of lean ($R = 0.9135$).

Average backfat thickness proved to be most closely associated with the index of lean for any weight grouping of carcasses. Length of carcass was second.

The addition of other carcass measurements to the regression equation did not significantly increase the precision in estimating the index of lean.

A set of objective carcass grade specifications was developed. The specifications included carcass weight, body length and backfat thickness.

The individual cutout values of the 600 carcasses were computed, based on the prices of wholesale cuts in 1949. The carcasses were then graded according to the specifications developed. The variance of the values within each grade was only about one-third as great as the variance in values between grades.

Thus, if hogs were purchased on a carcass weight and grade basis, the use of this grade standard would improve the accuracy of pricing hogs by two-thirds over using carcass weight alone.

The carcass values were carried back to a live-hog basis by using the relationship between grades of hogs and average yields found in other research. Using these average yields instead of the individual animal yields, it was found that, if hogs were purchased on a liveweight and carcass grade basis, the accuracy of pricing hogs would be improved by one-third over pricing hogs on a liveweight basis only.

Some objective evaluation for other characteristics such as softness and color of fat, size of eye muscle in loin, etc., would increase the accuracy of grading when used in conjunction with the proposed system.

Further research is needed to show the effects on cutout values of these other characteristics. The value of the by-products for the different weights and grades also should be taken into account.

Objective Grade Specifications for Slaughter Barrow and Gilt Carcasses[1]

BY OWEN L. BROUGH[2] AND GEOFFREY SHEPHERD[3]

Much research has been done to increase the technical efficiency of livestock production. The results have been greater meat output per unit of feed, or improvements in the quality of the product or both. But relatively less emphasis has been placed on the accuracy of pricing livestock. Research is needed to show the ways in which the livestock marketing system may be altered to increase its general market efficiency.

The marketing system must be efficient both in operation and pricing to provide society with a means for allocating scarce resources among producers and for distributing scarce goods and services among consumers so that they will be used best. This study is concerned directly with the problem of pricing efficiency.[4]

The efficiency of the price mechanism in marketing hogs is dependent on several economic and institutional factors. The first is the degree of knowledge of the forces influencing the buyers' and sellers' prices in the market. Knowledge depends on ability of buyers and sellers to determine the true value of hogs offered for sale, on the availability of a market language (grade standards) that can be used to describe hogs accurately and on the extent to which the market news is disseminated to all concerned in the market.

A second factor affecting the efficiency of the price mechanism is the characteristics of the pork market. In the United States, the hog is bought as an entirety but is sold by the meat processor as many wholesale cuts and various processed meats. It is difficult to reflect the value of these various cuts and processed meats accurately in the prices of live hogs.

A third factor is the physical basis on which sale is made. At the present time, most hogs are sold on a liveweight basis. If they could be sold on a carcass weight and grade basis, the value of the cuts could be reflected in the price of the carcasses more accurately than in the price of live hogs, because the characteristics of the cuts could be more accurately determined and the differences in value resulting from different degrees of "fill" would be by-passed.

The specific purpose of this study is to develop objective grade specifications for slaughter hog (barrow and gilt) carcasses that would differentiate carcasses on the basis of the wholesale yield of cuts and trimmings. The development of satisfactory and acceptable carcass grade standards that reflect the cutout values of the carcass is an important economic and technical problem to be solved in pricing livestock on a weight and grade basis.

CHARACTERISTICS OF HOG CARCASS GRADES

Previous work in the field of grade standard development has demonstrated that there are wide variations among carcasses that are classified alike with respect to sex, use, age and weight. Butcher-type hog carcasses of a given weight range differ in quantitative characteristics. These variations are due to differences in conformation, finish and quality.

Conformation refers to the build or shape of the carcass reflecting the relative size of the various cuts. Carcasses that have superior conformation yield a high proportion of the most desirable cuts.

Finish refers to the degree of fatness. It includes the quantity and the quality of fat on the outside and on the inside of the body and the amount and distribution of fat between the muscles and tissues.

Quality refers to the character of the flesh and fat. Quality is determined by the tenderness,

[1] Project 984, Iowa Agricultural Experiment Station. This study is a part of the regional project of the North Central Livestock Marketing Research Committee.

[2] Owen L. Brough is now associate professor at the State College of Washington, Pullman, Washington.

[3] The data upon which this study is based were obtained from the Iowa Packing Company, Des Moines, Iowa, in 1948. The authors are also indebted to Emil Jebe and Raymond Jessen of the Department of Statistics, and Elliott Clifton, John Nordin and Earl O. Heady of the Department of Economics and Sociology, Iowa State College, for their helpful suggestions and criticisms.

[4] By *pricing efficiency* is meant accurate reflection by the pricing mechanism to the producer of the consumers' demands for different quantities and qualities of goods and services. By *operational efficiency* is meant the combination of scarce resources into their optimum use in assembling, processing, transporting, storing, sorting, distributing and similar operations, to add form, time and place utility to the raw farm products in moving them from the farm to the ultimate consumer.

palatability of the meat, strength of muscle fiber, color of the lean and fat meat, amount and strength of the connective tissue, the character of the intercellular fat, relationship between edible meat and fat, and the size and character of the bones.

The grade of a hog carcass depends on all three of these factors (conformation, finish and quality). These factors are continuous variables. No sharp lines can be drawn between the upper limits of one grade and the lower limits of another. Yet some division must be made, upper and lower limits established, and the corresponding grade specifications described so that carcasses can be classed into relatively homogeneous grades.

Because human error may sometimes creep into the subjective evaluation of these characteristics, the buyer or seller may believe that the grade of a particular carcass is too high or too low because a particular grader has a definite bias one way or the other in his estimation of these characteristics. It is possible for equally well-qualified graders to disagree as to the exact grade of a borderline carcass. Also, graders located in different parts of the country could differ in their grading.

A possible solution to this problem would be to develop a set of objective grade specifications. When the buyer or seller questions the proper classification of a carcass, an objective measurement of some characteristic would permit the grader to decide the issue objectively. If this method of grading resolved the question without an observable bias, the conflicting views of the two interested parties could be more easily reconciled.

PREVIOUS RESEARCH CONCERNING OBJECTIVE GRADE STANDARDS FOR SLAUGHTER BARROWS AND GILTS

Several other investigators have been concerned with the problem of objective grade standards for slaughter hogs. Shepherd et al. found that backfat thickness and carcass length were related to grade.[5] Engelman found that the five primal cuts plus lean trimmings could be used to determine the value of carcasses. His study also indicated that backfat thickness and carcass length were the two objective measurements which were most closely related to the value of the carcass.[6] Similar results have been found in other studies.[7] Federal grades based on carcass specifications developed in these and other studies were made official in September 1952.[8]

DEVELOPMENT OF OBJECTIVE CARCASS GRADE STANDARDS

Source and Character of Data

The data for the present analysis to be used in the development of objective carcass standards were obtained at the Iowa Packing Company, Des Moines, Iowa, from June 15, 1948, through July 20, 1948. Measurements were taken and recorded on 600 hog carcasses. After the carcasses were measured, they were cut, and the weights of the wholesale cuts and trimmings were recorded. Trained government graders placed quality grades on the four major cuts (hams, loins, picnics and bellies).

SELECTION OF CARCASSES

A stratified random sample of carcasses based on weight of carcass and on backfat thickness was selected. Carcasses were selected so that equal numbers of carcasses fell in each weight group for the weight ranges in which most Iowa hogs are marketed. The individual weights of carcasses selected were intended to vary from 105 to 225 pounds. This range in carcass weight approximates the liveweight range from 165 to 315 pounds. The entire range was divided into 12 consecutive weight groups each having a 10-pound weight range. An attempt was made to have 50 carcasses in each of the weight groups. Two weight groups contained 52 carcasses and one group contained 47 carcasses. The other nine groups contained from 48 to 51 carcasses per group.

Sampling by weight alone, however, would not suffice for the purpose of this study. Finish, quality and conformation vary within any 10-pound weight group of carcasses. An attempt was made, therefore, to sample as wide a range of variation of carcasses within each weight group as possible, regardless of the numbers in which these physical categories come to market.

From previous work on this subject, it was observed that there is a high degree of relationship between backfat thickness and the degree of finish. Degree of finish is a subjective term used to show the amount of fat the animal has as well as the distribution of that fat. It also is related to conformation of the carcass. The use of some objective measure of the degree of finish instead

[5] Shepherd, Geoffrey, Fred J. Beard and Arval Erickson. Could hogs be sold by carcass weight and grade in the United States? Iowa Agr. Exp. Sta. Res. Bul. 270. 1940. pp. 454-456.

[6] Engelman, Gerald, Austin A. Dowell, Evan F. Ferrin and Phillip A. Anderson. Marketing slaughter hogs by carcass, weight and grade. Minn. Exp. Sta. Tech. Bul. 187. 1950.

[7] For examples see: Wiley, James R., Don Paarlberg and R. C. Jones. Objective carcass factors related to slaughter hog value. Indiana Agr. Exp. Sta. Bul. 567. December 1951; Heming, George F., and Merrill B. Evans. Market hogs can be accurately graded. Ohio Agr. Exp. Sta. Res. Bul. 728. June 1953; and North Central Livestock Marketing Research Committee. Objective carcass grade standards for slaughter hogs. North Central Regional Publication No. 30. June 1952.

[8] "Tentative standards for grades of pork carcasses and fresh pork cuts were issued by the United States Department of Agriculture in 1931. These tentative standards were slightly revised in 1933 and published in Circular 288. New standards for grades of barrow and gilt carcasses were proposed by the United States Department of Agriculture in 1949. These standards represented the first application of objective measurements as grades to grades for pork carcasses. Slight revisions were made in the proposed standards prior to promulgations by the Secretary of Agriculture, as the official United States Standards for grades of barrow and gilt carcasses, effective September 12, 1952." USDA, Production and Marketing Administration, Service and Regulatory Announcement No. 171. September 1952.

of such terms as very fat, less fat, etc., seemed desirable. Therefore, it was decided to select carcasses on the basis of 5-millimeter graduations of average backfat thickness. Backfat thickness was found to range from 20 to 70 millimeters. Each classification of a given carcass weight was to represent an equal portion of the total physical range in variation.

It was impractical to obtain adequate numbers of animals in certain weight and grade categories. It was not necessary that the number of carcasses in each cell should be exactly the same because the analyses in this phase of the study were of the regression type, assuming continuous variables.

The carcasses for each cell were selected at random. Carcasses with serious shackle bruises, ham, loin or belly bruising, or with jowls noticeably trimmed for diseased glands were discarded.

The distribution of carcasses by weight and backfat thickness is shown in table 1. The lack of overfinished lightweight and underfinished heavyweight carcasses is evident. Carcasses in those categories were scarce.

MEASURING, CUTTING AND GRADING OF CARCASSES

After the carcasses had been in the cooler for 24 hours, they were measured and weighed. The measurements included: body length, ham length, backfat thickness at the first rib, last rib and the last lumbar vertebra, width of each shoulder, circumference of each ham and thickness of belly pocket. The measurements were recorded in millimeters. The carcasses were cut the same day that the measurements were taken. The usual procedure was to use the regular power cutting machinery and cutting tables immediately after the regular cutting crew had completed their day's operations. The cuts and various trimmings were weighed on scales graduated in pounds and ounces, and the weights were recorded. Because this phase of the study was primarily concerned with actual differences between carcasses, rather than the variations in the particular product obtained by the cutting gang in a packing plant, it was considered advisable to standardize the cutting procedure for each hog carcass.[9]

To evaluate the relationship between the various measurements of the carcass and the probable frequency with which the wholesale cuts are discounted for quality reasons, the hams, loins, picnics and bellies were graded by United States government graders on the basis of the United States standards for the various wholesale cuts. These cuts were not downgraded for bruises, trimmings or faulty workmanship.

Analysis of Data

PRELIMINARY ANALYSIS

One approach to the problem of developing objective carcass grade standards is to determine whether some physical measures can be found which have a functional relationship with the weights of certain wholesale cuts, or combinations of cuts, and the quality grade of the cuts.

For a given weight group of carcasses, the data available were the series of measurements mentioned previously and the weights of various wholesale cuts and trimmings. To let each cut and trimming become a dependent variable and try to predict the weight of each of these cuts by use of the physical measurements as independent variables, would become an unwieldy problem. It would be especially unwieldy when 12 carcass weight groups, as shown in table 1, were involved.

Some combination of similar cuts appeared to have some merit. The hams, loins, butts and picnics make up the lean cuts which are, generally, all high in value. Bellies and lean trimmings are also high-value cuts.

[9] For detailed description of measurements used and cutting procedure, see: Engelman, G. et al., op. cit., pages 54-56.

TABLE 1. FREQUENCY DISTRIBUTION OF CARCASSES SELECTED FOR CUT-OUT TESTS CLASSIFIED BY WEIGHT OF CARCASS AND AVERAGE BACKFAT THICKNESS.

Carcass weight (pounds)	Average backfat thickness (millimeters)										Total
	20.0 to 24.9	25.0 to 29.9	30.0 to 34.9	35.0 to 39.9	40.0 to 44.9	45.0 to 49.9	50.0 to 54.9	55.0 to 59.9	60.0 to 64.9	65.0 to 69.9	
105 to 114.9	6	9	12	12	8	2					49
115 to 124.9	6	10	13	12	4	3	1				49
125 to 134.9	8	8	8	8	9	6	3				50
135 to 144.9	3	6	11	9	8	9	4	1			51
145 to 154.9	2	6	10	11	6	10	5	2			52
155 to 164.9		1	7	7	8	10	7	8	1		49
165 to 174.9		2	2	7	10	12	11	3	3		50
175 to 184.9		2	3	7	6	12	7	8	6	1	52
185 to 194.9			2	8	9	6	9	8	4	4	50
195 to 204.9			1	4	10	6	7	10	10	1	49
205 to 214.9			2	2	9	9	9	11	8	2	52
215 to 224.9			1	1	9	9	9	4	5	8	47
Total	25	45	71	87	99	92	71	55	38	17	600

Other combinations of cuts that were considered desirable were the fat cuts[10] and the skeletal cuts.[11] The four lean cuts when trimmed make up about 50 percent of the total weight of the carcass, the bellies and lean trim about 22 percent, the fat cuts about 20 percent and the skeletal cuts about 8 percent.

The four lean cuts usually make up about 60 to 65 percent of the total value of the carcass, and the skeletal cuts, only about 4 percent of the value of the carcass. Visual observation of scatter diagrams indicated that the total weight of the four lean cuts seemed to have the greatest functional relationship with the other combinations of cuts. For brevity, the weight of the four lean cuts as a percentage of the carcass weight will be referred to as the *index of lean.*

The physical measurements which were given an exploratory examination for use as independent variables to predict the index of lean were as follows:

1. Average backfat thickness
2. Length of body[12]
3. Average length of ham
4. Average circumference of ham
5. Thickness of belly pocket
6. Average width of shoulder
7. Average width of ham
8. Index of ham[13]
9. Index of muscling in ham[14]
10. Index of muscling in shoulder[15]

For various carcass weight groups, scatter diagrams were plotted showing the relationship between the various measurements and the index of lean. Visual evaluations of the simple relationships indicated that the order of the various measurements in their ability to independently predict the index of lean was as follows:

1. Average backfat thickness
2. Length of body
3. Index of muscling of ham
4. Length of ham
5. Index of ham
6. Index of muscling of shoulder

The relationships appeared to be linear. Backfat thickness showed the closest correlation with the index of lean. Body length was second to backfat thickness. Thickness of belly pocket came third.

[10] Fat back, jowls and fat trim.

[11] Spareribs, neck bones, front feet, hind feet and tail.

[12] Measured from the junction of the last cervical and first thoracic vertebra to the lowest point of the aitchbone.

[13] The index of ham was calculated by dividing the circumference of the ham by the length of ham. This measurement reflects the conformation of the ham.

[14] The index of muscling of ham was computed by subtracting twice the thickness of backfat at the last lumbar vertebra from the total width of hams. This measure is an estimate of the thickness of the lean meat or muscling of the ham.

[15] The index of muscling in the shoulder was similarly calculated by subtracting twice the backfat thickness at the first rib from the total width of shoulder.

To test more accurately which of the five variables (backfat thickness, length of body, index of muscling of ham, index of ham and length of ham) should be used as independent variables, the multiple regression of the index of lean on these five variables was calculated for the 145- to 155-pound carcass weight class. The reduction in the error sum of squares effected by including index of muscling of ham, index of ham and length of ham was not significant at the 0.05 probability level.

It was concluded, therefore, that the measures other than average backfat thickness and length of body, for carcasses of equal weight, do not contribute sufficiently to accuracy to justify their inclusion as independent variables to predict the index of lean.

ANALYSIS OF ENTIRE SAMPLE DATA

An interrelationship existed between the independent variables, backfat thickness, length of body and total weight of carcass.

The estimates of the various parameters in the regression equation are as follows:[16]

$$Y = 58.951923 - 0.180750X_1 - 29.094702 \frac{X_1}{X_2} + 1.267703 \frac{X_3}{X_2}$$

where Y = index of lean, X_1 = backfat thickness, X_2 = total weight and X_3 = length.

The multiple correlation coefficient (R) was 0.913 and the corresponding coefficient of determination (R^2) was 0.834. The standard error of estimate was 1.74 index numbers. The standard partial regression coefficients for the independent variables were all significantly different from zero at the 0.01 probability level.

The standard partial regression coefficients indicate that backfat thickness is the most important variable and that the variable backfat thickness divided by carcass weight is second in importance as predictor of index of lean.

For any given carcass weight and length, the index of lean decreases as average backfat thickness increases. In other words, as the hog becomes fatter the index of lean decreases. Also, for any given weight and backfat thickness, the index of lean increases as the hog becomes longer.

The index of lean is an approximate measure of the conformation of a hog carcass. It measures the relative proportion of fat and lean cuts making up the carcass.

The index of lean is also an approximate measure of the degree of finish. The relative proportion of fat cuts is related negatively to proportion of lean cuts. The index of lean is, therefore, the converse of degree of finish when used to describe carcasses. As hog carcasses increase in degree of finish, they decrease in index of lean.

The index of lean is also associated with the

[16] For further detail see Appendix A.

quality of the carcass. As was explained previously, the quality of the carcass is partly determined by the quality of lean cuts. The combined distribution of the grades for the four cuts (bellies, loins, hams and picnics) by the index of lean is given in Appendix B, table 2-B. Data in this table indicate that there is a relationship between the index of lean and the distribution of carcass grades. No cuts were graded down when the index of lean was 40 or below. No cuts were graded in the top grade when the index of lean was 58 or above. No cuts were graded down to Grade 3 when the index of lean was 50 or less.

So far, emphasis has been placed on showing the similarity between the important subjective grade criteria (conformation, finish and quality) and the same criteria measured by objective methods. It has been explained that there is a logical relationship between the index of lean and subjective carcass grade criteria. An objective system of grading hog carcasses, based on the index of lean, could approximate the three grade criteria mentioned above. It can be seen (Appendix B, table 2-B) that the quality grades of the particular cuts are related to the quantitative measure of conformation and finish (index of lean).

To set the boundary lines between grades, based on the index of lean, some method was required to specify the desired backfat thickness, carcass length and carcass weight at each interval of index of lean. The interval chosen for the index of lean was 1 percent. These values of backfat thickness were computed by fixing the values for index of lean, carcass weight and length and then solving the regression equation for backfat thickness. The values of backfat thickness (in millimeters) were then multiplied by a conversion factor to change them to inches.[17]

The intervals used were 1 index number for index of lean, 1 inch for carcass length and 10 pounds for carcass weight (see Appendix B, table 1-B).

A carcass with an index of lean of 40 is a highly finished carcass, as only 40 percent of the weight of the carcass consists of hams, loins, picnics and butts. At the other extreme, a carcass with an index of lean of 60 is very lean, for 60 percent of its weight consists of these high-value cuts and 40 percent consists of the lower value fat and skeletal cuts.

Development of a Grade Standard

One of the fundamental problems was to combine carcass weight, length and backfat thickness information in such a way as to provide a set of hog carcass grade specifications that is practical, simple and has economic significance.

In this study, the index of lean was used as the basic physical measure for setting grade boundaries.

The next step was to decide upon the number of classes or grades to be used. Grades could be based on a 1-point gradation for the index of lean. This would result in about 20 grades. It is obvious that such a schedule would be impractical for classifying hog carcasses in a packing plant due to the minute gradations in backfat thickness among grades within a given weight group. Small errors in the measurement of backfat thickness, carcass length and weight would result in carcasses being out of grade from one to two grades.

Because the estimated standard error of estimate was 1.74 points of the index of lean, it was concluded that there should be a separation of the midpoint of the grades by at least 3.0 points for the index of lean.

The next step was to decide what index of lean to use as the grade boundaries. There was only a small probability that the primal cuts of the carcass would be graded down because of inferior quality to grades No. 3 or Cull for values of the index of lean below 51 or 52 (see Appendix B, table 2-B). The graphic illustration of the quality grade distribution by index of lean for the combination of the four lean primal cuts (hams, loins, picnics and bellies) is given in fig. 1. One logical boundary for a grade would be the point where certain cuts are beginning to be discounted for lack of quality. It was assumed that this point was where the index of lean was 51 or 52.[18] Starting from this point, grade boundaries could be established in either direction. The frequency distribution of carcasses in the sample according to the index of lean is shown in fig. 2. The distribution is approximately normal. The mean of this distribution is 49.2 for index of lean.

It can be argued that the middle grade should be centered near the mean of the distribution, thus making it possible to have an equal number of grades on either side of the mean of the distribution. It can be observed, also, that the upper limit of the middle grade for a grade standard with a 3.0 index of lean interval and centered at the mean of 49.5 would fall near an index of lean of 51. As a result of these considerations, it was decided to establish grades with the upper limit of the middle grade at an index of lean of 51 and set the remaining boundaries at intervals of 3.0 indexes of lean in both directions.

The next step was to determine the intervals of carcass weight to be used. Live hogs are at present sorted by weight. Most of the prices are quoted on the basis of 20- to 30-pound weight in-

[17] It was concluded that inches would be a better measure to be used in setting up practical grade standards, mainly, because the accuracy needed in practical work will not require as detailed a measurement as the data used in this study. Only at the boundary lines between grades will accuracy in measurements need to be equal to that used in the sample for this study. Also, most farmers and packers are more familiar with this system of measurements.

[18] Several of the cuts (hams, loins, picnics and bellies) that are sold to government agents must be graded on the basis of government grade standards. Cuts sold through other channels are generally graded according to packer grade standards. No absolute information was available as to relative characteristics of the two systems. From observation and conversation with federal graders, the authors concluded that only carcasses having the quality characteristics of government Grade 3 and Cull are generally discounted in value. The four cuts of the sample that were graded were graded by federal graders according to government standards.

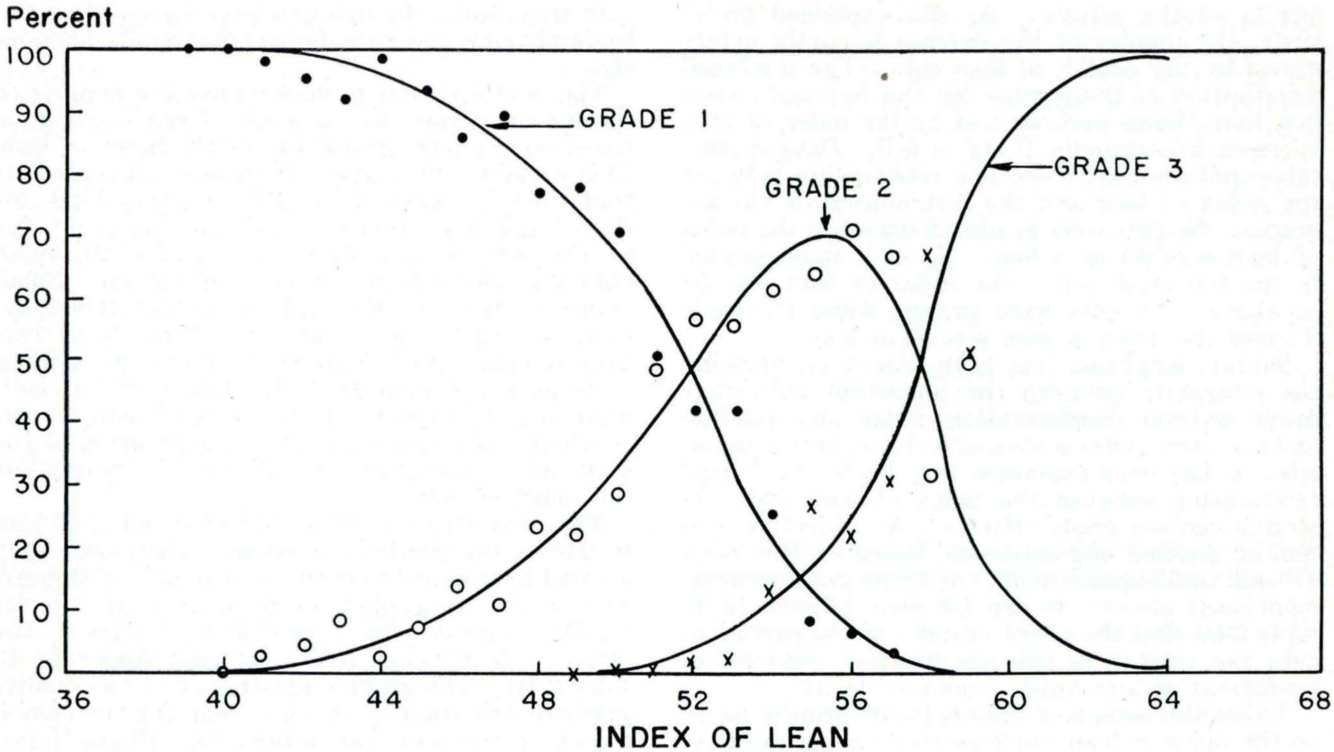

Fig. 1. Percent distribution of four primal cuts (hams, loins, bellies and picnic hams) in each grade according to the index of lean.

tervals. A 30-pound liveweight corresponds to approximately a 20-pound carcass weight interval. Therefore, from practical considerations it seemed logical to use a 20-pound carcass weight interval.

The next step was to determine the size of the length interval for each 20-pound carcass weight interval. Table 2 shows that the distribution of carcasses by length for each 20-pound weight interval approximates the normal distribution. The mean length for each weight group increased at an approximate rate of 1 inch for every 20 pounds. The table also shows average range of length for each 20-pound weight group is approximately 7 inches.

It was decided to use 2-inch intervals of length for each 20-pound weight group. The middle 2-inch interval in each weight group was centered approximately at the mean length and the middle 2-inch length interval was increased by 1 inch for each successive weight group. With this arrangement, over 50 percent of the carcasses fell in the middle length interval of each weight group. The remainder of the carcasses were distributed approximately equally between the two extreme length intervals.

Grade Standard A was developed on the basis of the above proposed condition. An attempt was made to keep the average index of lean comparable within each grade regardless of weight and length. The midpoint of one grade was separated from the midpoint of the next grade in each of the weight groups by a difference of 3.0 for the index of lean. The required backfat thickness at the margin of each grade for the midpoints of 2-inch intervals of length within each 20-pound carcass weight interval is shown in table 3.

The grade designations within each weight group are indicated by numbers rather than by grade terms. Carcasses in Grade 7 would be very fat, and those in Grade 13 would be very lean. It is believed that carcasses increase in value per 100 pounds with increase in the index of lean up to the point where certain cuts are discounted for lack of quality, or up to the point where the cuts are discounted due to excess weight. For example, carcasses in Grade 7 would be worth less per pound

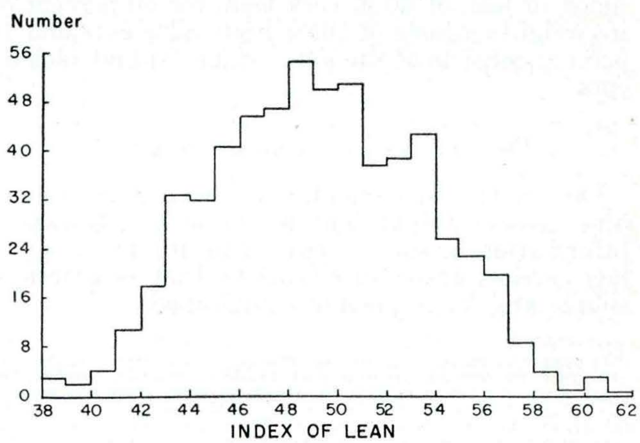

Fig. 2. Distribution of 600 butcher hog carcasses according to index of lean.

TABLE 2. PERCENTAGE DISTRIBUTION OF CARCASSES BY LENGTH AND WEIGHT INTERVALS.

Carcass length	Carcass weight (pounds)						
	100 to 120	120 to 140	140 to 160	160 to 180	180 to 200	200 to 220	220 to 240
(inches)	(percent)	(percent)	(percent)	(percent)	(percent)	(percent)	(percent)
25	16	3					
26	25	8	2				
27	27	25	18	4			
28	19	22	19	12	7	2	
29	10	33	25	27	18	7	3
30	3	7	22	33	27	25	19
31		2	10	15	21	27	23
32			3	8	19	23	26
33			1	1	6	10	18
34					2	5	9
35						1	2
Total percent	100	100	100	100	100	100	100

TABLE 3. GRADE STANDARD A.

Carcass weights	Equivalent liveweight (approx.)	Length of carcass	Carcass grades					
			7*	8†	9‡	10§	11**	12††
			Backfat thickness at margin	Backfat thickness at margin	Backfat thickness at margin	Backfat thickness at margin	Backfat thickness at margin	Backfat thickness at margin
(lbs.)	(lbs.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
80 to 100	124 to 151	Less than 25	2.0	1.8	1.5	1.3	1.1	0.8
		25 to 26.9	2.0	1.8	1.6	1.4	1.1	0.9
		27 and over	2.1	1.9	1.6	1.4	1.2	0.9
100 to 120	151 to 178	Less than 26	2.2	1.9	1.6	1.4	1.1	0.8
		26 to 27.9	2.2	1.9	1.7	1.4	1.1	0.9
		28 and over	2.2	2.0	1.7	1.4	1.2	0.9
120 to 140	178 to 205	Less than 27	2.3	2.0	1.7	1.4	1.1	0.8
		27 to 28.9	2.3	2.0	1.7	1.4	1.2	0.9
		29 and over	2.4	2.1	1.8	1.5	1.2	0.9
140 to 160	205 to 231	Less than 28	2.4	2.1	1.8	1.4	1.1	0.8
		28 to 29.9	2.4	2.1	1.8	1.5	1.2	0.9
		30 and over	2.5	2.2	1.8	1.5	1.2	0.9
160 to 180	231 to 257	Less than 29	2.5	2.2	1.8	1.5	1.2	0.8
		29 to 30.9	2.5	2.2	1.9	1.5	1.2	0.8
		31 and over	2.6	2.2	1.9	1.6	1.2	0.9
180 to 200	257 to 283	Less than 30	2.6	2.2	1.9	1.5	1.2	0.8
		30 to 31.9	2.6	2.3	1.9	1.6	1.2	0.8
		32 and over	2.7	2.3	2.0	1.6	1.2	0.9
200 to 220	283 to 309	Less than 31	2.7	2.3	1.9	1.6	1.2	0.8
		31 to 32.9	2.7	2.3	2.0	1.6	1.2	0.8
		33 and over	2.7	2.4	2.0	1.6	1.2	0.9
220 to 240	309 to 335	Less than 32	2.7	2.3	2.0	1.6	1.2	0.8
		32 to 33.9	2.8	2.4	2.0	1.6	1.2	0.8
		34 and over	2.8	2.4	2.0	1.6	1.3	0.9
240 to 260	335 to 362	Less than 33	2.8	2.4	2.0	1.6	1.2	0.8
		33 to 34.9	2.8	2.4	2.0	1.6	1.2	0.8
		35 and over	2.9	2.5	2.1	1.7	1.3	0.9

* Average index of lean equals 40.5.
† Average index of lean equals 43.5.
‡ Average index of lean equals 46.5.
§ Average index of lean equals 49.5.
** Average index of lean equals 52.5.
†† Average index of lean equals 55.5. Average index of lean for grade 13 equals 58.5.

than those in Grade 8 because they carry a higher proportion of low-value fat cuts and a lower proportion of high-value lean cuts. Likewise, carcasses in Grade 9 would be worth less per pound than those in Grade 10. Carcasses in Grades 11 and 12 would probably be discounted for inadequate finish. Under long-time price relationships, carcasses in Grade 10 probably command the highest price.

Development of an Alternative Grade Standard

An alternative Grade Standard B with five grades was developed. The midpoint of the middle grade was set at 50 for index of lean and with a grade midpoint difference of 4.0 for the index of lean. The same weight and length intervals were used as in Grade Standard A. Specifications for Grade Standard B are given in table 4. The difference in backfat thickness between grade limits for Grade Standard A is approximately 0.3 inch for the lightweight groups and approximately 0.4 inch for the heavy, carcass weight groups. Grade Standard B has backfat thickness differences between grade limits of approximately 0.4 inch for light carcasses and 0.5 for heavy carcasses. The wider differences in the required backfat thickness would result in fewer backfat measurements because there are fewer grade boundaries, thus making it possible to decrease grading time and reduce the probability of misgrading a carcass.

The use of Grade Standard A or Grade Standard B in the modern packing plant would probably create no serious practical problems. As the carcasses moved along the carcass rail line from the killing floor to the cooler, they could first be weighed and the carcass identification number and weight recorded and attached to each carcass. The grader could first look at the weight of the carcass and determine the weight-group classification. Next, he could classify the carcass into one of the three length classifications. This also should be quite simple. Finally, the average backfat could be determined and, consequently, the grade could be determined. The whole process would take only a few seconds. The relative speed with which graders could grade carcasses is not known. Further investigation will be required to develop this information.

Physical Effectiveness of Alternative Standard

Before attempting to assess the economic effectiveness of carcass standards in sorting or classifying carcasses into homogeneous groups with respect to value differences, an evaluation of the ability of these standards to measure physical differences seemed desirable.

Hog carcasses in the sample were graded into the various grades according to the carcass mea-

TABLE 4. GRADE STANDARD B.

Carcass weights	Equivalent liveweight (approx.)	Length of carcass	Carcass grades 8*	9†	10‡	11§
			Backfat thickness at margin	Backfat thickness at margin	Backfat thickness at margin	Backfat thickness at margin
(lbs.)	(lbs.)	(in.)	(in.)	(in.)	(in.)	(in.)
80 to 100	124 to 151	Less than 25	1.8	1.5	1.2	0.9
		25 to 26.9	1.9	1.6	1.3	1.0
		27 and over	2.0	1.6	1.3	1.0
100 to 120	151 to 178	Less than 26	2.0	1.6	1.3	0.9
		26 to 27.9	2.0	1.7	1.3	1.0
		28 and over	2.1	1.7	1.4	1.0
120 to 140	178 to 205	Less than 27	2.1	1.7	1.3	0.9
		27 to 28.9	2.1	1.7	1.4	1.0
		29 and over	2.2	1.8	1.4	1.0
140 to 160	205 to 231	Less than 28	2.2	1.8	1.3	0.9
		28 to 29.9	2.2	1.8	1.4	1.0
		30 and over	2.3	1.8	1.4	1.0
160 to 180	231 to 257	Less than 29	2.3	1.8	1.4	0.9
		29 to 30.9	2.3	1.9	1.4	1.0
		31 and over	2.4	1.9	1.5	1.0
180 to 200	257 to 283	Less than 30	2.3	1.9	1.4	0.9
		30 to 31.9	2.4	1.9	1.4	1.0
		32 and over	2.4	2.0	1.5	1.0
200 to 220	283 to 309	Less than 31	2.4	1.9	1.4	0.9
		31 to 32.9	2.4	2.0	1.5	1.0
		33 and over	2.5	2.0	1.5	1.0
220 to 240	309 to 335	Less than 32	2.5	2.0	1.4	0.9
		32 to 33.9	2.5	2.0	1.5	1.0
		34 and over	2.5	2.0	1.5	1.0
240 to 260	335 to 362	Less than 33	2.5	2.0	1.5	0.9
		33 to 34.9	2.6	2.0	1.5	1.0
		35 and over	2.6	2.1	1.5	1.0

* Average index of lean equals 42.
† Average index of lean equals 46.
‡ Average index of lean equals 50.
§ Average index of lean equals 54. Average index of lean for grade 12 equals 58.

TABLE 5. PERCENT OF THE TOTAL CARCASSES OVER, UNDER AND CORRECTLY GRADED FOR EACH CARCASS GRADE FOR GRADE STANDARDS A AND B*.

	No. of carcasses in each grade	Carcasses undergraded two grades	Carcasses undergraded one grade	Carcasses correctly graded	Carcasses overgraded one grade	Carcasses overgraded two grades	Total
		(percent)	(percent)	(percent)	(percent)	(percent)	(percent)
Grade Standard A							
Grade 7	18	0.0	0.0	44.4	50.0	5.6	100.0
Grade 8	85	0.0	2.3	61.2	36.5	0.0	100.0
Grade 9	135	0.0	9.6	59.3	31.0	0.0	100.0
Grade 10	157	1.3	20.3	61.8	15.3	1.3	100.0
Grade 11	117	0.9	25.6	62.4	11.1	0.0	100.0
Grade 12	72	2.8	30.6	56.9	9.7	0.0	100.0
Grade 13	16	12.5	50.0	37.5	0.0	0.0	100.0
Weighted average		1.2	17.8	59.5	21.0	0.5	100.0
Grade Standard B							
Grade 8	71	0.0	0.0	57.7	42.3	0.0	100.0
Grade 9	167	0.0	6.6	70.0	23.4	0.0	100.0
Grade 10	193	0.0	16.6	76.2	7.2	0.0	100.0
Grade 11	133	0.0	25.6	72.2	2.2	0.0	100.0
Grade 12	36	0.0	41.6	58.3	0.0	0.0	100.0
Weighted average		0.0	15.3	70.4	14.3	0.0	100.0

* Undergraded refers to those carcasses classified into a lower numerically designated grade and overgraded refers to carcasses classified into a high numerically designated grade.

surements of backfat thickness, carcass weight and body length. The carcass grade was then compared with the grade determined by the index of lean for each carcass. A tabular analysis of the percent of the carcasses graded correctly and incorrectly is given in table 5.

For Grade Standard A, only about 60 percent of the carcasses were correctly graded, and for Grade Standard B, about 70 percent of the carcasses were correctly graded. For Grade Standard B, no carcasses were out of grade by two grades, while for Grade Standard A, about 2 percent of the carcasses were out of grade by two grades. For both standards, the percent overgraded was about the same as the percent undergraded. Grades 7, 8 and 9 generally were overgraded more often than they were undergraded, and grades 11, 12 and 13 were undergraded more often than they were overgraded.

The sample distribution of carcasses according to the index of lean (fig. 2) explains this last peculiarity. It is impossible for Grade 7 to be undergraded and impossible for Grade 13 to be overgraded. The distribution of carcasses in grades 7, 8 and 9 is concentrated at the upper limits of each grade, and the distribution of carcasses in grades 10, 11 and 12 is concentrated near the lower limits of the grade. Therefore, for grades 7, 8 and 9, a greater number of the carcasses will be graded in a higher numerical grade than a lower grade. The opposite situation can be seen for grades 11, 12 and 13.

After observing the foregoing test of the relative effectiveness of the two carcass grade standards in sorting carcasses into homogeneous groups according to physical differences, it was concluded that Grade Standard B probably had superior merit as a tentative carcass grade standard. Grade Standard B would be more practical for use in a modern packing plant. There are fewer margins between grades, thus eliminating the necessity of additional carcass measurements for carcasses that fall at the grade margins. It is believed that carcasses can be graded efficiently on the basis of a difference of 0.4 to 0.5 inch average backfat thickness per grade under usual packing house conditions. To use a grade standard with differences of less than 0.4 inch for backfat thickness, would probably require too close a measurement for practical use. On the other hand, it seems desirable to accept a grade standard in which the physical characteristics within grades or classifications are as homogeneous as possible without becoming impractical.

Relationships Between the Wholesale Cuts and Trimmings and the Index of Lean

The relationships between each of the component wholesale cuts and trimmings and the index of lean were determined by computing their regressions on the index of lean. The values of the regression coefficients, standard error of the regression coefficient, standard error of estimates and the correlation coefficients for each of the wholesale cuts, trimmings and skeletal parts to the index of lean are shown in table 6. The individual percentages of each separate cut and trimming for each index of lean were also determined. The location and slope of the regression line of each of the 14 wholesale cuts and trimmings with respect to the index of lean are indicated in figs. 3 and 4.

Observation of scatter diagrams indicated that the relationships between the index of lean and the percent of wholesale cuts are all linear. The percent lean cuts and trimmings, (hams, loins, picnics, butts, lean trim and extra lean trim) and the skeletal cuts (spareribs, neck bones, front feet, hind feet and tail) all are positively related with the index of lean while the percent fat cuts (bellies, fat backs, fat trim and jowls) are all negatively related.

TABLE 6. DISTRIBUTION OF THE PERCENT EACH WHOLESALE CUT IS OF CARCASSES WEIGHT CLASSIFIED BY INDEX OF LEAN.

Wholesale cuts and trimmings	Regression values	Standard error of regression coefficient	Correlation coefficients	Standard error of estimate	Index of lean																		
					41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
Lean cuts, bellies and lean trimmings	(b)	(s_b)	(r)	($s_{y.x}$)																			
Ham	0.376	0.006	0.927	0.649	16.08	16.46	16.84	17.21	17.58	17.96	18.34	18.71	19.09	19.46	19.84	20.22	20.59	20.97	21.34	21.72	22.10	22.47	22.85
Loins	0.297	0.007	0.867	0.729	11.91	12.21	12.50	12.80	13.10	13.39	13.69	13.99	14.28	14.58	14.88	15.18	15.48	15.77	16.07	16.36	16.66	16.96	17.25
Picnics	0.179	0.005	0.847	0.480	7.14	7.31	7.49	7.67	7.85	8.03	8.21	8.39	8.57	8.75	8.92	9.10	9.28	9.46	9.64	9.82	10.00	10.18	10.36
Boston Butts	0.148	0.005	0.762	0.535	5.87	6.02	6.17	6.32	6.47	6.62	6.76	6.91	7.06	7.21	7.36	7.50	7.65	7.80	7.95	8.10	8.24	8.39	8.54
Total: 4 lean cuts	1.000	0.000	1.000	0.000	41.00	42.00	43.00	44.00	45.00	46.00	47.00	48.00	49.00	50.00	51.00	52.00	53.00	54.00	55.00	56.00	57.00	58.00	59.00
Bellies	−0.370	0.014	−0.730	1.480	20.57	20.20	19.83	19.46	19.09	18.72	18.35	17.98	17.61	17.24	16.87	16.50	16.13	15.76	15.39	15.02	14.65	14.28	13.91
Lean trim	0.060	0.007	0.326	0.740	2.88	2.94	3.00	3.06	3.12	3.18	3.24	3.30	3.36	3.24	3.48	3.54	3.60	3.66	3.72	3.78	3.84	3.90	3.96
Ex lean trim	0.036	0.002	0.504	0.260	0.25	0.29	0.33	0.36	0.40	0.43	0.47	0.51	0.54	0.58	0.61	0.65	0.68	0.71	0.75	0.79	0.83	0.86	0.90
Total: lean cuts plus bellies plus trim	0.726	0.009	0.939	1.133	64.70	65.43	66.16	66.88	67.61	68.33	69.06	69.79	70.51	71.24	71.96	72.69	73.41	74.13	74.86	75.59	76.32	77.04	77.77
Fat cuts																							
Fat back	−0.535	0.010	−0.904	1.078	12.38	11.85	11.31	10.78	10.24	9.71	9.17	8.64	8.10	7.57	7.03	6.50	5.96	5.42	4.89	4.36	3.82	3.28	2.75
Fat trim	−0.333	0.012	−0.763	1.204	13.77	13.43	13.10	12.76	12.43	12.10	11.77	11.43	11.10	10.76	10.43	10.10	9.77	9.44	9.10	8.77	8.43	8.10	7.77
Jowls	−0.073	0.005	−0.533	0.498	4.09	4.02	3.94	3.87	3.80	3.72	3.65	3.58	3.50	3.43	3.36	3.28	3.21	3.14	3.07	2.99	2.92	2.85	2.77
Total:fat cuts	−0.942	0.012	−0.957	1.218	30.24	29.30	28.35	27.41	26.47	25.53	24.59	23.65	22.70	21.76	20.82	19.88	18.94	18.00	17.06	16.12	15.17	14.23	13.29
Skeletal cuts																							
Spareribs	0.071	0.002	0.792	0.235	1.81	1.88	1.95	2.03	2.10	2.17	2.24	2.31	2.38	2.45	2.52	2.59	2.66	2.73	2.81	2.88	2.95	3.02	3.09
Neck bones	0.055	0.003	0.666	0.261	1.10	1.16	1.21	1.26	1.32	1.38	1.43	1.48	1.54	1.59	1.64	1.70	1.76	1.82	1.87	1.92	1.98	2.04	2.09
Front feet	0.038	0.002	0.663	0.185	1.98	1.01	1.05	1.09	1.12	1.16	1.20	1.24	1.28	1.32	1.36	1.40	1.43	1.47	1.50	1.54	1.58	1.62	1.66
Hind feet	0.044	0.002	0.723	0.179	1.05	1.09	1.14	1.18	1.22	1.27	1.31	1.35	1.40	1.44	1.49	1.53	1.58	1.62	1.66	1.71	1.75	1.79	1.84
Tail	0.008	0.001	0.468	0.067	0.12	0.13	0.14	0.15	0.16	0.16	0.17	0.18	0.19	0.20	0.20	0.21	0.22	0.23	0.24	0.24	0.25	0.26	0.26
Total: skeletal cuts	0.217	0.006	0.839	0.599	5.06	5.27	5.49	5.71	5.92	6.14	6.35	6.56	6.79	7.00	7.22	7.43	7.65	7.87	8.08	8.29	8.51	8.73	8.94
Total: all cuts					100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

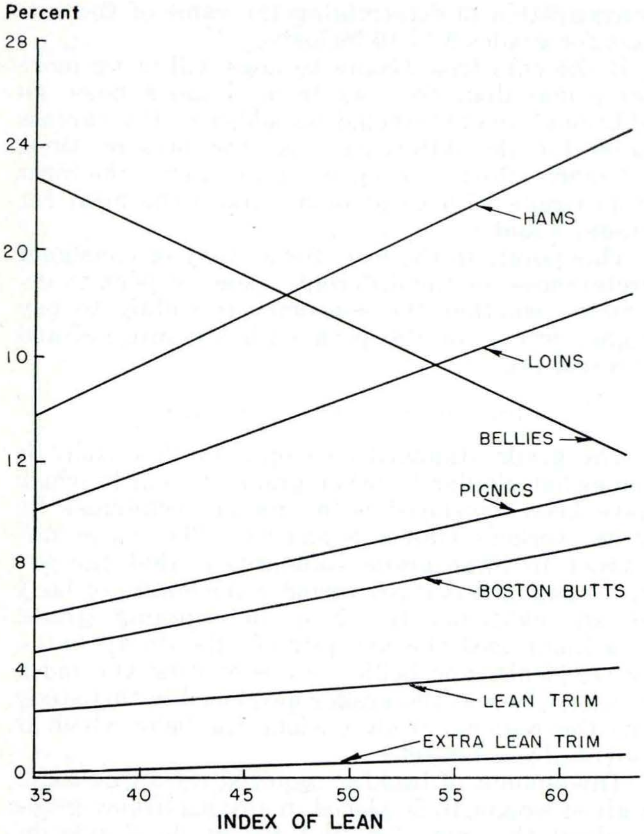

Fig. 3. Percentage relationship of lean cuts, lean trimmings and bellies, to the index of lean.

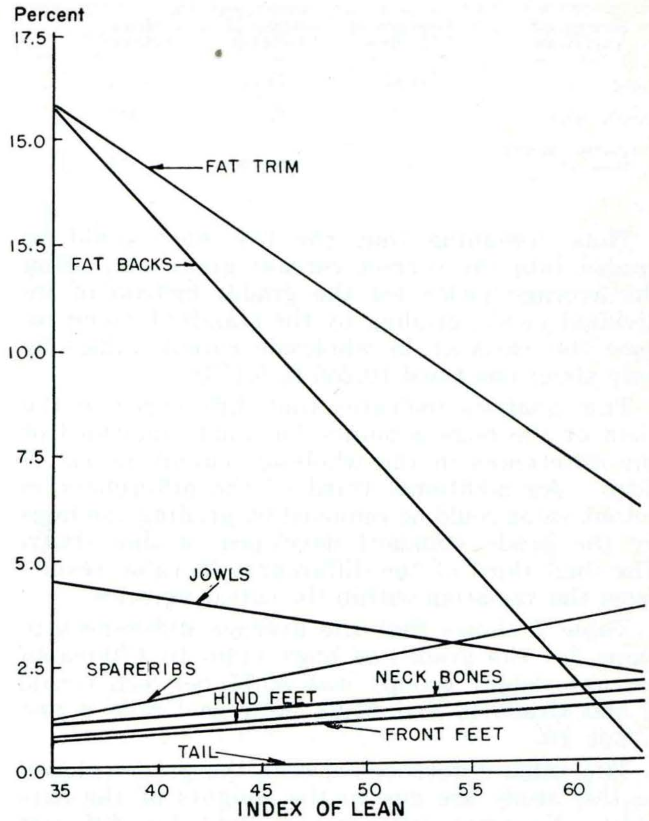

Fig. 4. Percentage relationship of the fat cuts and skeletal cuts to the index of lean.

EVALUATION OF THE GRADE STANDARD

The effectiveness of the grade standard in separating the hog carcasses into groups with different cutout values was determined by the following procedure:

The average wholesale price in 1949[19] for each of the wholesale cuts was multiplied by the weight of that cut from each carcass. These values were summed for each carcass to get the value of the carcass. The carcass value was divided by the weight of the carcass and multiplied by 100 to get the value of each carcass per 100 pounds. The two grades (11 and 12) that were supposedly discounted for lack of quality were not included because the correct amount of this discount was not known.

Using the 140- to 170-pound weight group, the following analysis of variance was computed:

Source of variation	Degrees of freedom	Sums of squares	Mean squares
Total	179	182.22	1.018
Grade class	2	122.39	61.195
Carcasses within class	177	59.83	0.338

[19] Wholesale prices are available in: North Central Livestock Marketing Research Committee. op. cit. Appendix C. p. 56.

This shows that grading the carcasses by the grade standards reduces the variability in carcass wholesale cutout values by about two-thirds (1.018 to 0.338).

Although the individual dressing percents were not obtained in this study, some estimate of the effectiveness of this grade standard in reflecting live values can be made by using average yields by grades obtained from another study. The following relationship between yield and grade was found by Engelman.[20] Grade 10 dressed 0.9 percent less than Grade 9 and 1.8 percent less than Grade 8. Although the grade specifications in Engelman's study were slightly different from the grade specifications in this study, the differences in yields between grades should be about the same.

Using the following yields:

Grade 10 .... 70.0 percent

Grade 9 .... 70.9 percent

Grade 8 .... 71.8 percent

the following analysis of variance was computed:

[20] Engelman, G. et al., op. cit., p. 47.

Source of variation	Degrees of freedom	Sums of squares	Mean squares
Total	179	44.75	0.250
Grade class	2	14.13	7.065
Carcasses within class	177	30.62	0.173

Thus, assuming that the live hogs could be graded into the correct carcass grade and using the average yields for the grades instead of individual yields, grading by the standard would reduce the variance in wholesale cutout values by only about one-third (0.250 to 0.173).

This analysis indicates that differences in the yield of the hogs accounts for about one-third of the differences in the wholesale cutout values of hogs. An additional third of the differences in cutout value could be removed by grading the hogs by the grade standard developed in this study. The final third of the differences in value results from the variation within the carcass grades.

Table 7 shows that the average differences in value for the grades of hogs (140- to 170-pound carcass weight group) was $0.75 between Grade 8 and Grade 9, and $1.93 between Grade 8 and Grade 10.

The value difference between the grades shown in this study are due to the weights of the cuts only. No price difference is used for different grades of cuts. With this system of determining value, emphasis is placed on quantitative relationship of the carcass. The proportion of the high-value cuts in the carcass becomes the important consideration in determining the value of the carcass for grades 8 to 10 inclusive.

TABLE 7. AVERAGE WHOLESALE VALUE PER 100 POUNDS CARCASS WEIGHT, 1949 PRICES.

Grade	Value	Difference in value
8	$28.65	$0.00
9	29.40	0.75
10	30.58	1.93

If the cuts from Grade 10 hogs will bring more per pound than the cuts from Grade 8 hogs, an additional amount should be added to the carcass value for the difference. At the present time, not much effort is being made to market the meat from Grade 10 hogs at prices above the meat for grades 8 and 9.

This points to the need for a study of consumer preferences for the different grades of pork to determine whether the consumer is willing to pay higher prices for the pork with low internal and external fat.

Comparison of Grade Standards

The grade standard developed in this study is somewhat similar to other grade standards which have been developed with similar techniques by other workers (tables 8 and 9). The major difference in these grade standards is that the one developed in this study includes the length of body as an additional factor in determining grade. Engelman used the five primal cuts (loins, butts, hams, picnics and bellies) in computing the index of lean, whereas the grades developed in this study and the regional study exclude the belly which is essentially a fat cut.

The amount of backfat required for a carcass of a given weight to be placed in any particular grade is about the same for all these grade standards.

A grade standard similar to those discussed above was made official by the USDA in September 1952 (table 10). The official grade standard uses carcass weight or carcass length and backfat to determine grade.

Part of the variation in the cutout value of carcasses within grades might be reduced if the graders were trained to detect unusual carcasses, that is, carcasses that differ in physical proportions from the standardized carcass for the grade. This system could be especially useful for determining the grade of those carcasses falling on the boundary line between grades.

TABLE 8. HOG CARCASS GRADE STANDARD B, BASED ON BACKFAT THICKNESS AND CARCASS WEIGHT, MODIFIED 0.3 INCH RANGE OF BACKFAT PER GRADE,* WITH GRADE 10 CENTERED AT INDEX OF LEAN OF 70.0.†

Carcass weights, pounds	Equivalent liveweight (approx.), pounds		Carcass grades: margins	8 mid-points	margins	9 mid-points	margins	10 mid-points	margins	11 mid-points	margins	12 mid-points	margins
110-140 (125 average)	165-205	Backfat thickness, inches	2.3		2.0		1.7		1.4		1.1		0.8
		Index of lean	62.6	64.1	65.6	67.0	68.5	70.0	71.4	72.9	74.4	75.8	77.3
140-180 (160 average)	205-260	Backfat thickness, inches	2.5		2.1		1.8		1.5		1.2		0.9
		Index of lean	62.2	64.1	65.9	67.3	68.6	70.0	71.4	72.7	74.1	75.5	76.9
180-220 (200 average)	260-310	Backfat thickness, inches	2.6		2.2		1.9		1.6		1.3		0.9
		Index of lean	62.7	64.4	66.1	67.4	68.7	70.0	71.3	72.6	73.9	75.6	77.3
220-270 (245 average)	310-375	Backfat thickness, inches	2.7		2.4		2.0		1.7		1.3		1.0
		Index of lean	63.0	64.2	65.5	67.1	68.8	70.0	71.2	72.8	74.5	75.7	76.9
270-330 (300 average)	375-460	Backfat thickness, inches	2.9		2.5		2.1		1.8		1.4		1.0
		Index of lean	62.6	64.2	65.7	67.3	68.8	70.0	71.2	72.7	74.2	75.8	77.4

* Except for following weights and grades which have 0.4 inch range:
140-180 pounds—Grade 8; 180-220 pounds—Grades 8 and 12; 220-270 pounds—Grades 9 and 11; 270-330 pounds—Grades 8, 9, 11 and 12.

† Reproduced from Engelman, G. et al., op. cit., p. 29.

TABLE 9. TENTATIVE OBJECTIVE HOG CARCASS GRADE SPECIFICATIONS.*

	Carcass grades								
	8		9		10		11		12
Percent lean cuts									
— at midpoints			47.0		50.0		53.0		
— at margins		45.5		48.5		51.5		54.5	

Carcass weight groups	Mid-point weight	Backfat thickness	Backfat thickness	Backfat thickness	Backfat thickness
pounds		inches			
90-110	100	1.90	1.66	1.37	1.15
110-130	120	1.99	1.72	1.42	1.17
130-150	140	2.07	1.77	1.46	1.18
150-170	160	2.14	1.81	1.49	1.18
170-190	180	2.21	1.85	1.52	1.18
190-210	200	2.27	1.88	1.54	1.19
210-230	220	2.33	1.91	1.56	1.19
230-250	240	2.38	1.94	1.57	1.19

* Reproduced from: North Central Livestock Marketing Research Committee, op. cit. p. 15.

TABLE 10. WEIGHT AND MEASUREMENT GUIDES TO GRADES FOR BARROW AND GILT CARCASSES.*

Carcass wt. or carcass length	Grade: Choice No. 3	Choice No. 2	Choice No. 1	Medium	Cull
	(Average backfat thickness in inches)				
Under 120 lbs. or under 27 inches	2.0 or more	1.7 to 2.0	1.4 to 1.7	1.0 to 1.4	Less than 1.0
120 to 164 lbs. or 27 to 29.9 inches	2.1 or more	1.8 to 2.1	1.5 to 1.8	1.1 to 1.5	Less than 1.1
165 to 209 lbs. or 30 to 32.9 inches	2.2 or more	1.9 to 2.2	1.6 to 1.9	1.2 to 1.6	Less than 1.2
210 or more lbs. or 33 or more inches	2.3 or more	2.0 to 2.3	1.7 to 2.0	1.3 to 1.7	Less than 1.3

* Reproduced from Federal Register, October 6, 1951.

APPENDIX A

Preliminary analysis was designed to show the relationship between the weight of the four lean cuts (hams, picnics, loins and Boston butts) and the average backfat thickness, carcass weight and carcass length for each of the 12 carcass weight groups.

The relationship for each carcass weight group can be expressed as a linear equation including these three independent variables as follows:

$$(1)\quad Y = K + aX_1 + bX_2 + cX_3$$

where Y = total weight of the four lean cuts
K = a constant
X_1 = average backfat thickness
X_2 = total weight of the carcass
X_3 = length of the carcass.

It was found that the values of the partial regression coefficients of average backfat thickness on total weight of the four lean cuts changed as a linear function of total carcass weight. Therefore "a" in equation (1) can be expressed by the linear equation (2).

$$(2)\quad a = a' + dX_2$$

where a = the partial regression coefficients of backfat thickness on the weight of the four lean cuts for each weight group
a' = a constant
X_2 = total weight of the carcass.

This relationship in equation (2) was significantly different from zero at the 0.05 probability level.

Substituting equation (2) into the basic equation (1) gives equation (3) and can be expanded into equation (4).

$$(3)\quad Y = K + (a' + dX_2)\,X_1 + bX_2 + cX_3.$$

$$(4)\quad Y = K + a'X_1 + dX_1X_2 + bX_2 + cX_3.$$

As was mentioned previously, conformation is a quantitative or proportional concept, and the degree of finish is dependent on the relative amount of fat in the carcass. Therefore, it seemed logical that these carcass characteristics should be measured by some quantitative ratio. The ratio of the weight of the four lean cuts to the total carcass weight seemed to be a suitable ratio.

For equation (4), this ratio (index of lean) is $\frac{Y}{X_2} = Y'$. But, when the left side of the equation is divided by X_2, the right side must also be divided by X_2. Dividing both sides of the equation by total carcass weight (X_2) results in the following equation:

$$(5)\quad Y' = K\frac{1}{X_2} + a'\frac{X_1}{X_2} + dX_1 + b + c\frac{X_3}{X_2}$$

where Y' = index of lean
X_1 = average backfat thickness
X_2 = total weight of the carcass
X_3 = length of carcass.

Equation (5) was used for the multiple regression analysis of the entire sample. The various parameters for this multiple regression equation (5) were determined and it was found that the addition of the independent variable $1/X_2$ did not explain a significant ($P < 0.10$) amount of unexplained deviation in the index of lean to justify its inclusion in the equation. Therefore, the final equation (6) used for the analysis of the entire sample is as follows:

$$(6)\quad Y = K + b_1X_1 + b_2\frac{X_1}{X_2} + b_3\frac{X_3}{X_2}.$$

TABLE 2-B. DISTRIBUTION OF GRADES FOR THREE LEAN CUTS* AND BELLIES BY INDEX OF LEAN.

Cuts by grades	Index of lean																						
	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	Total
Grade 1																							
Bellies	2	4	11	18	31	32	38	40	41	38	36	35	12	7	7	1							
Loins	2	4	11	17	29	32	39	38	43	46	42	41	28	22	20	13	4	3				2	
Hams	2	4	10	17	31	30	35	39	40	39	38	29	14	13	21	4	2		1				
Picnics	2	4	11	17	30	32	40	41	44	46	40	40	23	23	24	8	2	2				2	
Total	8	16	43	69	121	126	152	158	168	169	156	145	77	65	72	26	8	5	1			4	1,589
Percent	100.0	100.0	97.7	95.8	91.7	98.4	92.7	85.9	89.4	76.8	78.0	71.1	50.7	41.7	41.9	25.0	8.7	6.3	2.8			33.3	
Grade 2																							
Bellies					2		3	6	6	17	14	16	25	30	33	19	12	9	2			2	
Loins				1	4		2	8	4	9	8	10	10	17	22	10	15	14	7	2	1	1	
Hams			1	1	2	2	6	7	7	16	12	22	24	25	22	21	18	19	7	2	1	3	
Picnics				1	3		1	5	3	9	10	10	15	16	19	14	14	15	8	1		1	
Total			1	3	11	2	12	26	20	51	44	58	74	88	96	64	59	57	24	5	2	7	704
Percent			2.3	4.2	8.3	1.6	7.3	14.1	10.6	23.2	22.0	28.4	48.7	56.4	55.8	61.5	64.1	71.2	66.6	31.2	50.0	58.3	
Grade 3 and culls																							
Bellies													1	2	3	6	11	11	7	4	1	1	
Loins															1	3	4	3	2	2			
Hams														1		1	3	1	1	2			
Picnics												1				4	7	3	1	3	1		
Total												1	1	3	4	14	25	18	11	11	2	1	91
Percent												0.5	0.6	1.9	2.3	13.5	27.2	22.5	30.6	68.8	50.0	8.4	
Total all cuts	8	16	44	72	132	128	164	184	188	220	200	204	152	156	172	104	92	80	36	16	4	12	2,384
Percent	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Loins, picnics and hams.