THE EFFECT OF MARKETING WEIGHT UPON MARGINAL FEED COSTS OF PORK AND LARD PRODUCTION

by

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TABLE OF CONTENTS

INDEX TO TABLES

INDEX TO APPENDIX TABLES

INDEX TO FIGURES

This thesis is based on part of an unfinished research project of the United States Department of Agriculture on input-output relationships in pork and lard production.

INTRODUCTION

Hogs consume almost half of the total corn produced in the United States,[1] and more than half of that grown in the Corn Belt. In addition to being the chief outlet for corn in the commercial production area, hogs also provide a large part of the flexibility of the livestock system. Because of the short production cycle, the number of hogs can be varied much faster than the number of beef cattle or dairy cows. In comparison with chickens, reasonably efficient production can be obtained with less specialized equipment, less labor, and a smaller proportion of feed supplements that are not produced on the farm.

The feed and gain of pigs after weaning have been repeatedly investigated and are probably established within narrower limits than the comparable figures for any other class of livestock. The feed and gain of the breeding herd, however, have been much less thoroughly investigated, so that the total feed cost of pork is not as adequately established. Slaughter tests showing the composition of the carcasses of hogs of different marketing weights have just been published (1943) but have not been used in connection with feed consumption to determine the feed costs of pork and lard.

The increased food needs of war caused an expansion of all livestock. An increase in both number of hogs and in marketing weights along with

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[1] Jennings, R.D., Feed Consumption by Livestock 1910-41. U.S. Dept. Agr. Circ. 670. p. 21. 1943.

expansion of beef cattle, dairy cows, and chickens reduced the feed supply to the point that reductions in livestock were necessary. To maximize food production from limited feed supplies the relationship between feed consumption and edible pork and lard production for hogs of different market weights is needed in order to change hog numbers and marketing weights in the right proportions. In order to get hogs marketed at any determined weight, the prices for hogs of different weights must be adjusted so as to induce the desired shift in marketing weight. While the optimum marketing weight for hogs from the standpoint of public policy depends upon changing nutritional (and psychological) needs, the basic data for determining optimum marketing weights for alternative nutritional assumptions are needed. Any decision on the range of marketing weights to be encouraged would be put into effect by a system of discounts and premiums for different marketing weights and by appropriate seasonal differentials. As changes in marketing weights can be made rather easily by the farmer, detailed information on the effect of seasonal price changes and of weight discounts on the alternatives available to the farmer is essential to the operation of any price policy.

The general aim of this study is to determine the basic relationship between feed consumption and pork production with emphasis upon the effect of changes in marketing weight. There are three specific objectives:

1. To determine the procedure for figuring the most profitable marketing weight from the farmer's standpoint.

2. To determine the influence of changes in marketing weight upon the efficiency of feed conversion into pork (live weight).

3. To determine the influence of shifts in slaughter weight upon the proportions of pork and of lard yield and to figure the feed costs of changes in these proportions.

REVIEW OF LITERATURE

The relationship between feed consumption and live-weight gain of hogs after weaning has been studied intensively for several decades. In 1898, Henry, in the first edition of Feeds and Feeding, summarized several hundred hog feeding experiments on dozens of rations ranging from artichokes to droppings from corn-fed steers. Periodic trials have shown the extent of feeding and breeding advances in recent years.

Case and Ross in a remarkably subtle analysis compared the difference in cost and in returns from marketing hogs at 200 and at 350 pounds for 1921-25 prices.[1] Despite the wide range in marketing weights compared, their procedure contained all the elements of the marginal cost and marginal returns analysis.

A series of farm management studies based on cost routes and farm records, together with new experiments, between 1920 and 1930 (shown below) established that between 450 and 500 pounds of concentrates were required per 100 pounds of pork (live weight) marketed. Annual summaries of Farm Business Association records in Iowa, Illinois, and Minnesota show a gradual decline in the feed requirements per 100 pounds gain in live weight during the past decade. Jennings, in his comprehensive survey of feed utilization estimated that 443 pounds of concentrates were fed per 100 pounds of live weight produced in 1929-33 and 424 pounds in 1938-40.[2] These investigations

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[1] Case, H. C. M. and Ross, Robert C. The Place of Hog Production in Corn-Belt Farming. Ill. Agr. Expt. Sta. Bul. 301, 1927.

[2] U.S.D.A. Circ. No. 670.

did not include slaughter tests to determine dressing percentages and composition of the hogs.

Among the best known experiments on the feed cost after weaning are those of Robison at Ohio 25 years ago.[1] Carefully selected barrows were hand-fed a full feed in dry lots and slaughtered at various weights to determine dressing percentages. In the first of the three trials, "To shorten the time of the experiment as much as possible, until a weight of 400 pounds was reached, the poorest-gaining pigs were slaughtered each time."[2] This selection apparently was repeated in the second trial, but not in the third ("Care was taken to select representative pigs."[3]) These trials show more efficient gains in the upper weight ranges than the experiments shown below.

Hogan and others[4] at Missouri combined feeding experiments with slaughter tests to show that as the marketing weight is increased (1) hogs become more efficient in conversion of energy, and (2) gains in protein become more costly while gains in fat become less expensive (both in terms of feed). These results, based upon the slaughter of one bacon type and one lard type hog at five marketing weights, show considerable variation,

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[1]Ohio Agr. Expt. Sta. Bul. 335, 1919. The experiments were actually begun from birth with the feed to the sow allocated to the pigs. The gain of the sow was not reported.

[2]Ibid. p. 550.

[3]Ibid. p. 567.

[4]Missouri Agr. Expt. Sta. Bul. 73, 1925.

but the fluctuation is within the range of the data here reported. In reference to the cost of protein independent of fat and vice versa they say: "It is probably unnecessary to add that we have not attempted to calculate separately the feed required for protein or fat formation."[1]

A method of obtaining separately the feed required for protein and fat formation and of deriving from this the marginal feed cost of pork and of lard is available and is applied in this study. Evidence is offered to show that the method yields valid results and that in practice pork and lard production can each be altered independently of the other.

In order to facilitate comparison, previous investigations related to the several sections of this report are placed adjacent to the results reported here. Thus other determinations of feed after weaning are summarized in that particular section, and likewise for breeding herd data, etc.

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[1]Ibid. p. 21.

SOURCE OF DATA AND PROCEDURE FOLLOWED

The general procedure followed and the data used fall into three parts corresponding to the three major sections of the thesis.

1. The feed and gain of pigs after weaning is based on three published and nine unpublished experiments, six from Iowa, two each from Illinois and Ohio, and one each from Purdue and Missouri. In these experiments[1] over 800 hogs were full-fed, mostly self-fed, balanced rations with shelled corn as the basal feed in dry lot. Concentrates fed are converted from pounds of feed to feed units in order to make more comparable the rations fed to hogs of different weights. This is the basis for determining the difference in feed cost for hogs marketed at different weights. Changes in cost are compared with changes in return or receipts as affected by the usual seasonal pattern and by the discounts on heavier weights. This is an application of the marginal cost and marginal returns analysis modified to fit the particular problem. Curiously enough, on the marginal revenue side, the closest parallel to the hog marketing problem is not atomistic competition, which actually prevails on the selling side, but monopolistic competition. This is because the hog keeps growing and the discounts for heavier weights apply not just to the increase in weight but to the whole hog--a simple fact, but one that differs from usual competitive conditions.[2]

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[1]Not conducted for this investigation. The summarizing of these data is not a part of the thesis.

[2]In monopolistic competition, the price received is influenced by the output of the individual producer, while in the marketing of hogs, the price is influenced by the weight at which hogs are marketed. This does not imply that the hog producer possesses any monopoly power.

2. In order to determine the total feed cost of pork, the feed and gain of the breeding herd must be added to the after-weaning figures. The breeding herd data are synthesized from (1) several published studies and one detailed unpublished investigation, and (2) market statistics of slaughter weights, proportion of sows slaughtered, sows farrowing, and pigs saved. The total feed cost of pork (live weight) is essential in order to figure the feed cost of pork and of lard in the third section, below, but it has some independent value to the farmer with alternative uses for feed. It is the measure usually employed to judge the efficiency of hogs, chickens, beef animals, etc., as converters of feed into food. While this measure is the appropriate one for the farmer for whom live weight marketed is the final consideration, more refined figures are available to measure the efficiency of hogs as feed converters. These are presented in the third section.

3. The feed-live-weight relationship, which is established in parts 1 and 2, is extended by slaughter tests showing dressing percentages and carcass composition, based on 64 intermediate type hogs slaughtered at Beltsville. A method is employed to make comparable the carcasses from hogs of different slaughter weights. The pork and lard produced per feed unit for different marketing weights can then be figured. The varying proportions of pork and lard at different marketing weights make possible the determination of the marginal feed cost of pork and of lard, each independent of changes in the other. The procedure is the Marshallian one for "joint products" in which the proportions of the products can be varied. This is accomplished by the use of a production indifference

curve. The indifference curve was employed by Edgeworth[1] and recently developed by Hicks and Allen.[2] The use here is similar to the terms of trade application by Haberler.[3]

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[1] Mathematical Psychics. London School of Economics and Political Science, Series of Reprints of Scarce Tracts in Economics and Political Science, No. 10, pp. 21-22. 1932.

[2] A Reconsideration of the Theory of Value. Economica, Vol. I, New Series, pp. 52-76 and pp. 196-219. 1934.

[3] The Theory of International Trade. Macmillan, 1936, pp. 186 ff.

AFTER WEANING DATA

While the calculation of the feed and growth after weaning relationship from the raw data of the 12 experiments is not a part of this study, the validity of the principal findings reported here depends upon their accuracy. For this reason a brief summary is included.

Growth Curve

The growth curve for all the hogs in the 12 experiments which provide the feed-after-weaning data used in this study[1] is based on full feeding in dry lot (figure 1). The rate of gain per day which is shown by the slope of the curve, increases rather rapidly from birth but at a decreasing rate until a weight of over 100 pounds is reached. The daily gain reaches a maximum of 1.70 pounds in the 200-210 pound range, but is only 10 percent less at 160 pounds, and again at 300 pounds. These hogs which are full-fed from weaning reach 100 pounds at 125 days from farrowing, 170 pounds in 170 days, and 225 pounds in 205 days.

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[1] A Gompertz growth curve is used. The figures for the chart are shown in Appendix I, Table 1. The same procedure is used for all the charts; the table number in Appendix I corresponds to the number of the chart which is based on it.

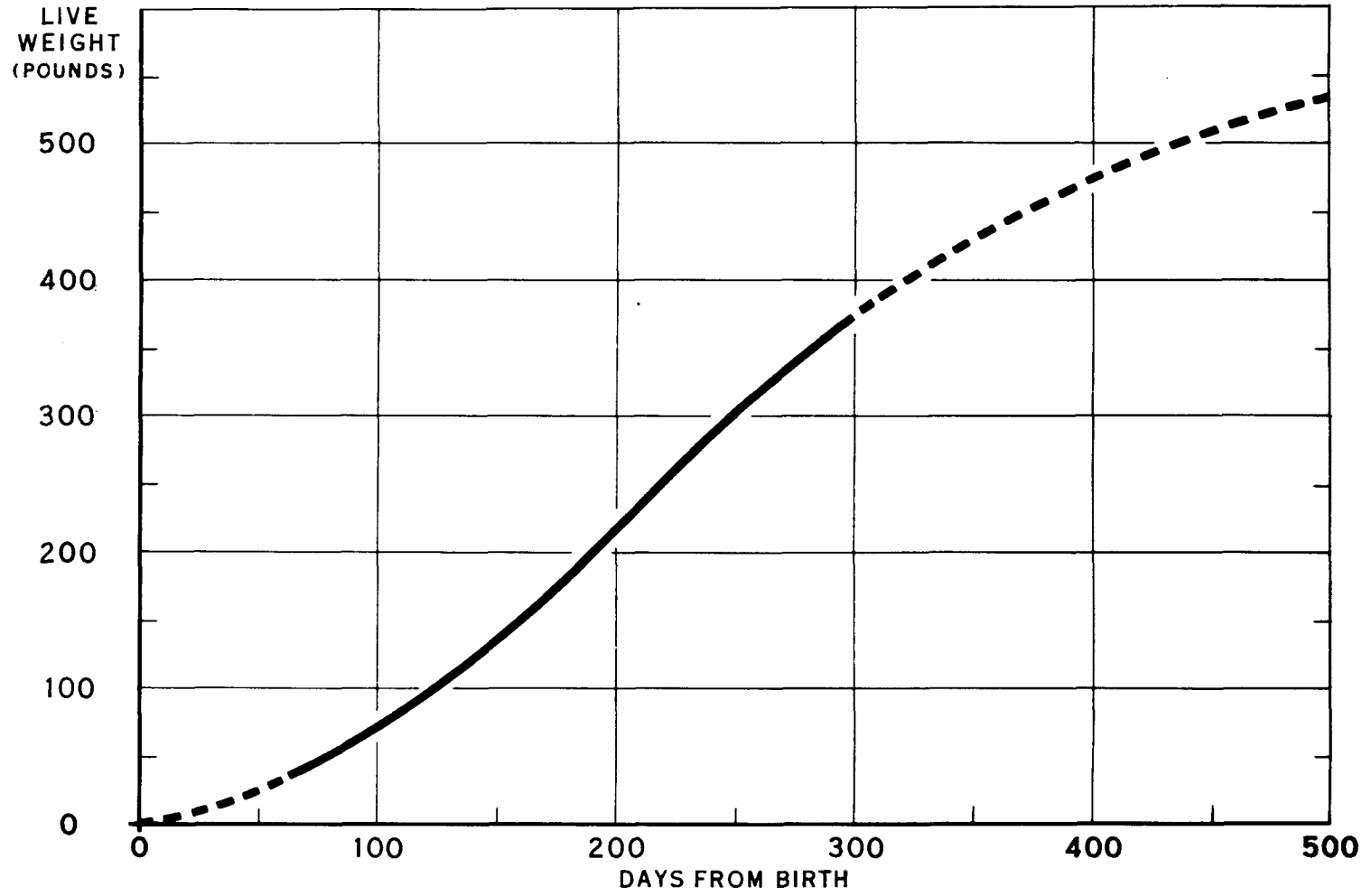

Fig. I. GROWTH CURVE FOR HOGS
BASED ON 800 HOGS IN 12 EXPERIMENTS

Feed and Gain After Weaning

The variation in the results obtained from the 12 feed-after-weaning experiments is shown in two ways. The first is by comparing the smoothed data from each experiment and the second is by showing the standard error of forecast. The fitted feed-live-weight curves adjusted to a weaning weight of 35 pounds for the 12 experiments (fig. 2) have a maximum difference between them of 18 pounds after 500 pounds of feed have been consumed after weaning, 30 pounds between the highest and lowest after feed consumption of 1,000 pounds, and 40 pounds at 1,500 pounds.[1] There is no logical reason for the Iowa experiments to be shown separately from the others except that 12 lines so close together cannot be distinguished readily. The variation that exists in the several experiments represents difference in supplements, in types of hogs, and in breeding strains. For example, the pigs in Iowa experiment No. 288 received superior supplements which may partially explain their efficient gain.

The average feed-live-weight curve for the 12 experiments (fig. 3) has a standard error of forecast (shown by broken lines) for a lot of 50 hogs of 26 pounds after a feed consumption of 500 pounds, 43 pounds at 1,000 pounds, and 55 pounds at 1,500 pounds.[2] In all, the records of more than 800 hogs are included. The Iowa and Indiana tests were made to compare

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[1] The standard error of estimate for each of the experiments is given in Appendix I, Table 2.

[2] The standard error of a forecast includes both the error of the function and the error of the individual lot. Schultz, H. The Standard Error of a Forecast from a Curve. Jour. Amer. Stat. Assn., Vol. XXV, New Series No. 170, pp. 139-185, June 1930.

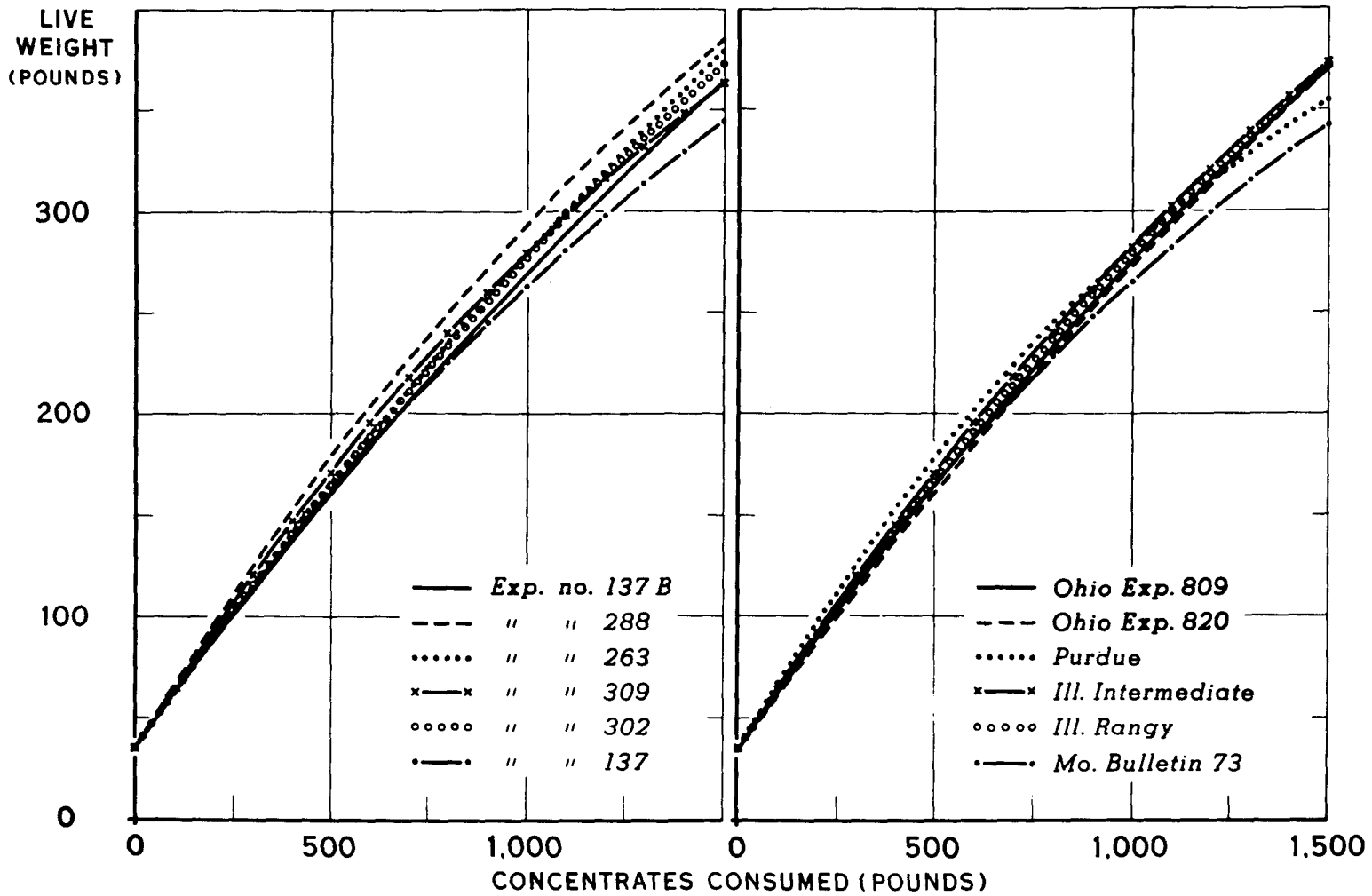

Fig. 2. FEED AND GAIN OF HOGS AFTER WEANING
SMOOTHED DATA OF 12 EXPERIMENTS ADJUSTED TO A WEANING WEIGHT OF 35 POUNDS

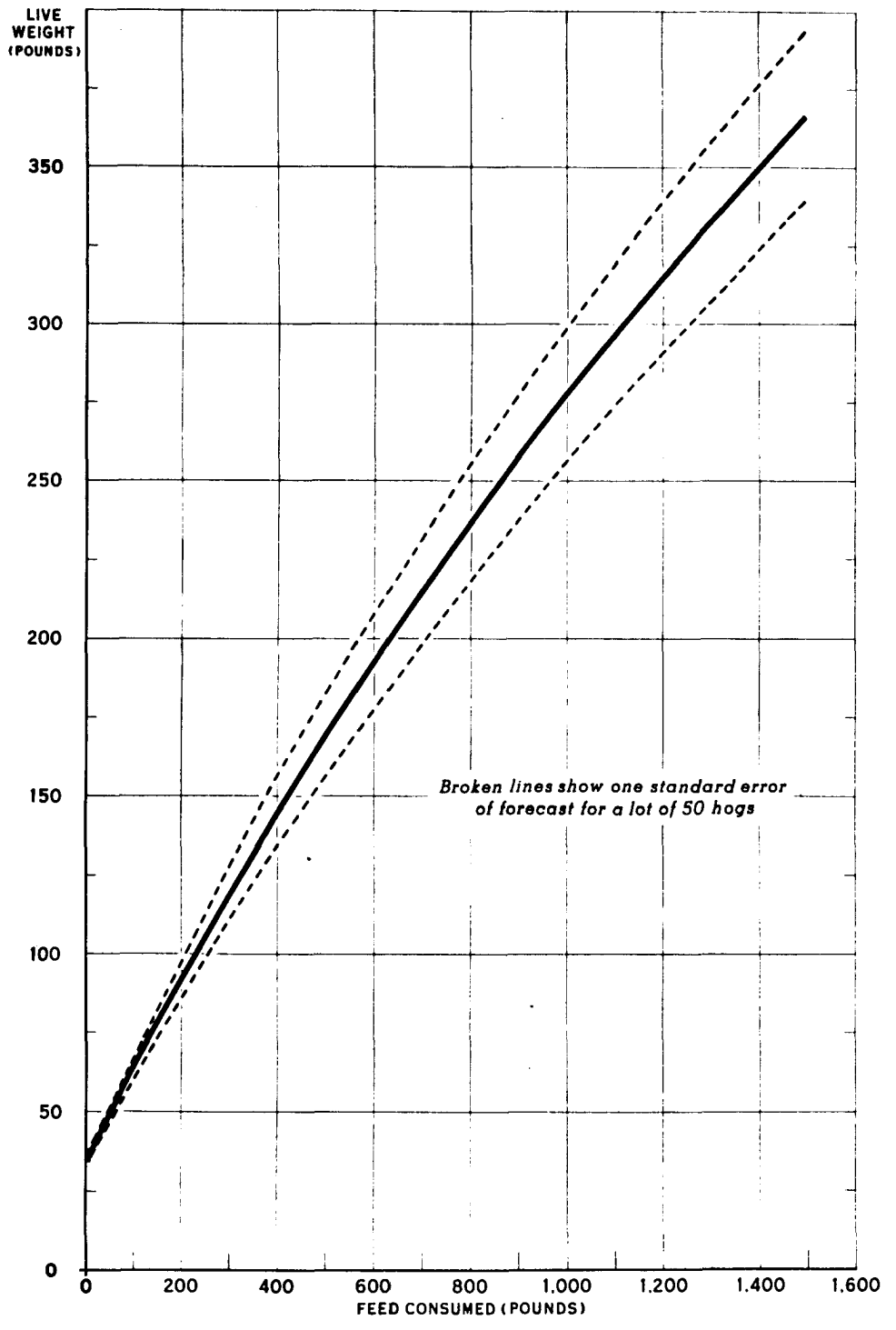

Fig. 3. FEED AND GAIN AFTER WEANING WITH STANDARD ERROR OF FORECAST FOR A LOT OF 50 HOGS

AVERAGE OF 12 EXPERIMENTS INVOLVING 800 HOGS FULL FED IN DRY LOT

various protein supplements and types of hogs (Iowa), the Illinois trials were type tests, the Ohio experiment was testing open pollinated versus hybrid corn, and the Missouri hogs were part of an animal nutrition study. In all the experiments, (1) the hogs were full-fed (mainly self-fed) in dry lot, (2) the basal feed was corn (usually shelled), (3) the more usual protein supplements were fed, (4) no severe or unusual treatment was employed, and (5) the treatments and feeding were the same throughout the experiments and similar to farm practice.

DETERMINATION OF THE MOST PROFITABLE MARKETING WEIGHT

A preliminary step in calculating the most profitable marketing weight is the establishment of the feed required per pound of gain for the whole range of marketing weights. The data summarized above must be interpreted so as to be applicable to the marketing problem.

The Influence of Changes in Feed Required per Pound of Gain on the Most Profitable Marketing Weight

In figure 3, live weight was shown to be a curvilinear function of pounds of feed consumed. Each successive 100 pounds of feed produces a smaller live-weight gain than the previous 100 pounds. The increasing feed requirements of hogs per pound of gain with increase in weight are significant in determining the most profitable marketing weight as has been pointed out by Robison[1] (and quoted by Morrison), Smith, Zeller and Ellis, and others. Except for a slight divergence from Robison's results already mentioned, the results below are consistent with the other studies. The comparisons selected differ from the ones made by the writers above, however, so that the interpretation of the meaning of the change in efficiency of gain is somewhat different. The relevant comparisons depend upon the decisions to be made from them; those made by the previous writers are important for some problems; the ones made below seem the most significant in answering the questions that are discussed.

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[1] Loc. cit.

The first difference is that feed units[1] are used instead of pounds of feed as a basis of measurement of efficiency. In comparing hogs of different weights, using feed units will give considerably different results than using pounds of feed. The same is true for hogs fed different rations. The pounds of feed used by pigs at light weights and at heavy weights differ in (1) protein content, (2) ability to produce a pound of gain at the same weight, and (3) cost per pound for the usual price relationships. The feed for hogs in different weight ranges is more comparable on all these bases if expressed in feed units rather than in pounds of concentrates.

Jennings, whose published feed unit values are used in this report, explains the idea behind it as follows: "The feed unit is the common denominator for all kinds of feeds...and is equal in feeding value to one pound of average corn.... It is a somewhat arbitrary measure, but it seems to be fairly satisfactory when a common measure is wanted of all kinds of feeds. It has the advantage of being easily understood as corn is the best known feed."[2]

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[1]A variation of the Danish feed unit system. Woll, F. W. The Feed Unit System for Determining the Economy of Production by Dairy Cows. Wis. Agr. Expt. Sta. Circ. of Information 37, p. 15, 1912.

[2]U.S.D.A. Circ. 670, p. 2. The feed unit values of one pound of the principal hog feeds used in the experiments are: Corn, 1.00; soybean oil meal, 1.75; tankage, 2.50; skim milk, dried, 2.00. For a complete list see ibid. p. 11. The feed unit value of protein supplements will change with large changes in the proportion of high protein feed available.

The second difference is more subtle but probably more important. Less emphasis will be placed upon the comparison of hogs from 0 to 100 pounds, with those from 100 to 200 pounds and from 200 to 300 pounds. Without claiming that such comparisons are of no consequence, the writer does maintain that they are not the critical comparisons for the two problems that are to be considered and if they are not the critical comparisons, emphasis on them may be misleading. The two problems are (1) the most profitable marketing weight (for pigs already weaned) and (2) the planning of the livestock enterprise for a year ahead. This latter decision must be made first; it usually involves a tentative decision on marketing weight, which is subject to change once the pigs are weaned. As the hogs approach marketing weight only the extra costs and extra returns of withholding the hog from the market for a period of time are important.

In planning the hog enterprise for a year ahead, some costs, such as breeding herd expenses, vary as the number of pigs to be farrowed and are not affected by changes in marketing weight. Other costs, such as labor, death losses, and housing are greater for younger pigs than for older ones and thus increase less than proportional to the growth of the butcher hog. Counterbalancing these two types of cost, which decline per 100 pounds of pork produced as the marketing weight of hogs increases, is an increasing feed cost per unit gain in weight. The feed cost of the butcher hog is such a large part of the additional cost of feeding hogs to heavier marketing weights that it may properly be used as an index of marginal cost. Marginal costs have limited significance, however, in the area in which average costs

have not reached a minimum point. It is important to determine the approximate marketing weight which represents this minimum cost point per 100 pounds of marketable pork produced in order to avoid the common error of attributing importance to the (rising) marginal cost of pork as long as average cost is falling.

On the basis of feed cost only, it will be shown below (fig. 7) that the cheapest pork is produced at about 200 pounds, but that the average feed cost is less than one percent higher at either 175 or 225 pounds. Using the figures from studies cited below (p.41) on costs other than feed, minimum average (total) costs would be reached nearer 225 pounds than 200 pounds--the exact weight does not matter for the limited use that is to be made of it.

A comparison, then, of the amount of feed needed to produce the gain between 100 and 150 pounds with the amount needed between 150 and 200 pounds is not the significant comparison either for planning marketing weights a year ahead or for the final decision on marketing weight. For the longer time decision, the feed cost for any weight range should be compared with the minimum cost figure, and for the specific decision, the feed (and other) costs for any period should be compared with the change in returns ignoring comparisons with other periods.

Using the feed cost[1] per 100 pounds live weight for 225 pound hogs as an index of 100, the index for the feed cost of 200 pound hogs is 99.6. The index for a change in weight from 200 to 225 is 104, and for 225 to 250

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[1]Unless otherwise stated, feed cost is measured in terms of feed units.

is 107. For the change in weight from 200 to 250, the index of feed costs is 106, while from 250 to 300 pounds it is 115. About 10 percent more feed is needed per hundredweight gain between 225 and 275 pounds than is required to produce a 225 pound hog. If these comparisons were based on pounds of feed instead of feed units they would average about as much again above 100; e.g., the 225 to 250 pound figure is 114 pounds instead of 107 feed units. The pounds-of-feed figures are not given, for they are not comparable, as explained above (p. 18).

The reduction in the apparent decline in efficiency of gain from the usual statement can be seen in the lower part of figure 4. The (incremental) gain in pounds live weight per hundred pounds of feed declines from almost 30 at weaning to 19 at 300 pounds. This is the usual way of expressing the decline in efficiency of gain. But the gain per 100 feed units drops only half as much--from 23 to 18. The area that is of crucial importance for deciding on the most profitable marketing weight is that between 200 and about 300 pounds, shown in the boxed section of the curves. In this area, the gain per 100 pounds of feed declines from 23 to 19 pounds, while the gain per 100 feed units drops from 21 to 18. Thus, "diminishing returns" in live-weight gain from feeding hogs to heavier weights is clearly evident, but the importance of the decline is exaggerated by stating it in terms of pounds of feed without explaining the difference in the composition and in the cost of rations at light and heavy weights. Economists have sometimes complained that in the feeding of dairy cows, diminishing returns were not

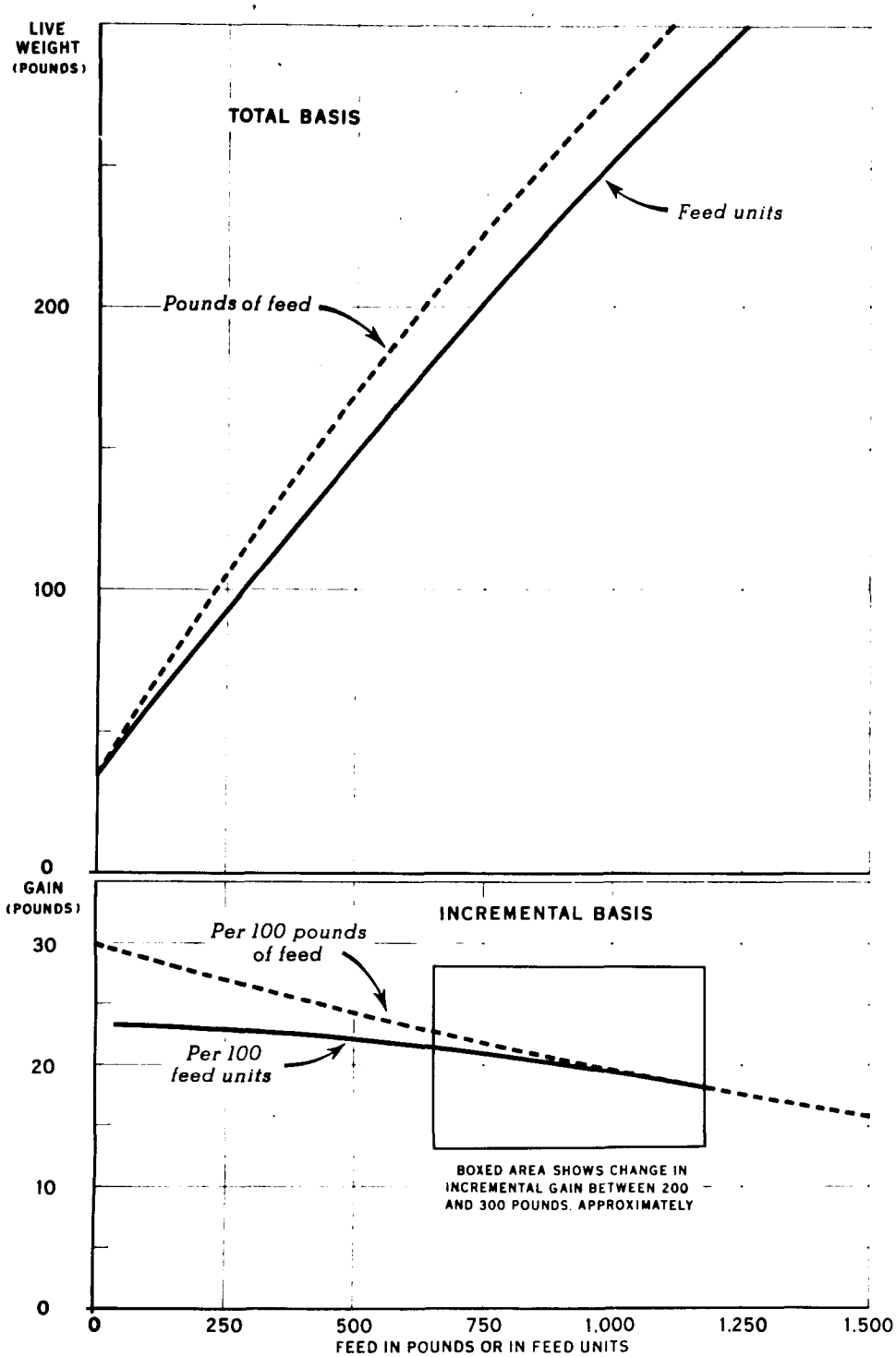

Fig. 4. FEED-LIVE-WEIGHT RELATIONSHIP FOR HOGS BASED ON POUNDS OF FEED AND ON FEED UNITS
TOTAL AND INCREMENTAL BASES

acknowledged;[1] in hog feeding experiments, however, the importance of diminishing returns may have been exaggerated.

In another sense the emphasis on diminishing returns from feeding hogs to heavier weights is objectionable. The theory of diminishing returns is based upon uniform units of inputs and outputs. The inputs of feed while not identical for hogs of different weights, if expressed in feed units are reasonably comparable. The gain (output) in live weight for hogs of different weight is not uniform, however in physical or chemical composition, or in any single significant measure available. The important diminishing returns problem in pork production must take into consideration the changes in carcass composition. Since live weight is neither a uniform nor a significant economic measure, even from the farmer's point of view, for he obtains different prices for the gain produced at different weights, the feed-live-weight relationship does not represent the diminishing returns problem. If output were measured in terms of calories, which in some respects is reasonable, there would be no diminishing returns within the limits of the data but rather increasing returns. In Part III, on the basis of slaughter tests a uniform method of measuring output will be developed. There it is contended that the true diminishing returns problem involves the feed-standardized-pork relationship with lard unchanged and the feed-lard relationship with pork unchanged.

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[1] U.S.D.A. Tech. Bul. 815, fig. 2, p. 6. 1942.

Marketing Weight--The Producer's Viewpoint

In deciding on the weight at which hogs can be most profitably marketed, the change in cost from keeping the hog for any given period, e.g., a week, must be balanced against the increase in value at which the hog can be sold. On the cost side the largest item is feed, while the labor involved is proportional to the feed cost.

Both the feed required for growth and the rate of growth have been shown; from these the change in feed cost for any additional feeding period can be figured. The feed that will be needed together with the accompanying gain in weight may be estimated rather closely, so that the change in cost, or marginal cost, for a week can be satisfactorily determined.

The change in the returns that can be obtained by withholding a hog from the market for a week can be estimated only subject to price changes. This change, however, is not wholly capricious. Two general movements have enough regularity that it is worth while to allow for them, (1) seasonal changes and (2) discounts on heavier hogs. Within a week they are rather small, but the percentage increase that can be obtained in the live weight of a hog in a week is likewise small. Thus a rapidly gaining hog at 225 pounds, if kept a week and meanwhile the market price drops 5 percent, will sell for no more at the end of the week than at the beginning despite the additional bushel of corn fed.

An interval of a week is appropriate for an actual problem of determining the most profitable marketing weight. For illustrative purposes, however, a monthly basis is used because it involves less detail, but the analysis is applicable to shorter periods of time which would be

used for practical problems. The only complication is that more calculations are needed--no new ones.

In neglecting consideration of "all other changes" the aim is not to minimize their importance. The other changes are neglected because from the short term view of the most profitable marketing weight they normally cannot be predicted.

The seasonal pattern of hog prices

The effect of the change in seasonal price is generally larger than the discount or premium received for holding hogs to heavier weights. The general seasonal pattern of hog prices is reasonably stable, except during periods of price control, when a sharp change in the pattern may be decided upon as a matter of policy. The seasonal trend may be illustrated by using the ratio to trend as determined by 12-months moving average, centered, for the 12-year period immediately preceding the price control period of World War II, Table 1.[1] The highest prices are during August and September when marketings are light. As the spring pigs are marketed the price breaks during October, November, and reaches the low point for the year usually in December, but occasionally in January. Then prices rise gradually through March, but are lower in April and May as the peak of the marketing of fall pigs is reached; finally prices rise and remain high until the new marketing season gets under way in October.

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[1]This period was used by G. Shepherd who pointed out that it was similar to 1922-41 average. Iowa State College Mimeo., 1943.

Table 1

Seasonal Pattern of Hog Prices, 1930-41
Ratio to 12-Months Moving Average, Centered
Good and Choice Barrows and Gilts, Chicago

Month	Ratio to 12-Months Moving Average	Month	Ratio to 12-Months Moving Average
January	92.4	July	108.1
February	96.6	August	111.3
March	99.1	September	112.0
April	96.3	October	99.8
May	96.0	November	91.2
June	99.4	December	87.5

The discount pattern for heavy hogs

Normally hogs marketed within the marketing range 200 to 240 pounds sell for higher prices than either lighter or heavier weights. In figure 5 a smooth curve has been drawn showing the average change in the pattern of discounts through the season based on the 1934-41 discounts and the 1930-41 seasonal prices. Beginning with October at the top, the pattern for each month is shown. In every month the maximum price is within the 200-to-250-pound marketing range, although in November and December the discount for heavier weights is less than ¢ .35 per hundredweight for 340-pound hogs. In July and August the discount is more than $1.00.

Alternative prices for hogs, allowing for growth

In deciding on the weight at which to market hogs the choice is not between 200 and 250 pounds in the same month, but between 200 pounds in one month and 250 pounds a month later for a hog on full feed. In figure 6 are shown the alternatives available, based on the average discounts shown in the previous figure together with the seasonal pattern (Table 1). Each line is labelled for the month in which the hogs were farrowed. Thus at the top of the sheet, the prices for January pigs are based on the July price for 150-pound hogs, the August price for 200 pounds, the September price for 250 pounds, etc. In the figure and hereafter in order to make the results of the experiments more comparable to Corn Belt practice, the assumption is made that the hogs are finished on full feed, but not that

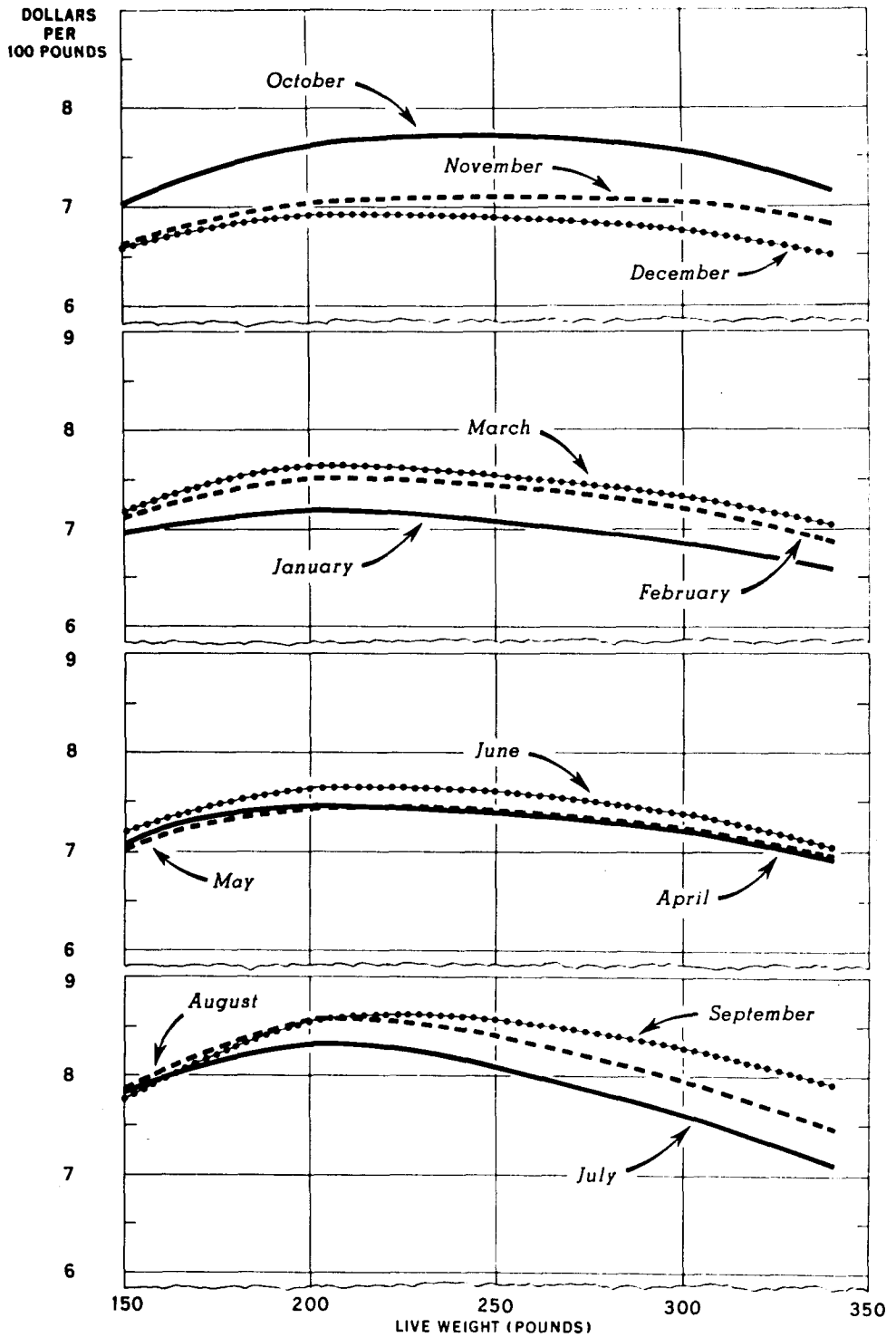
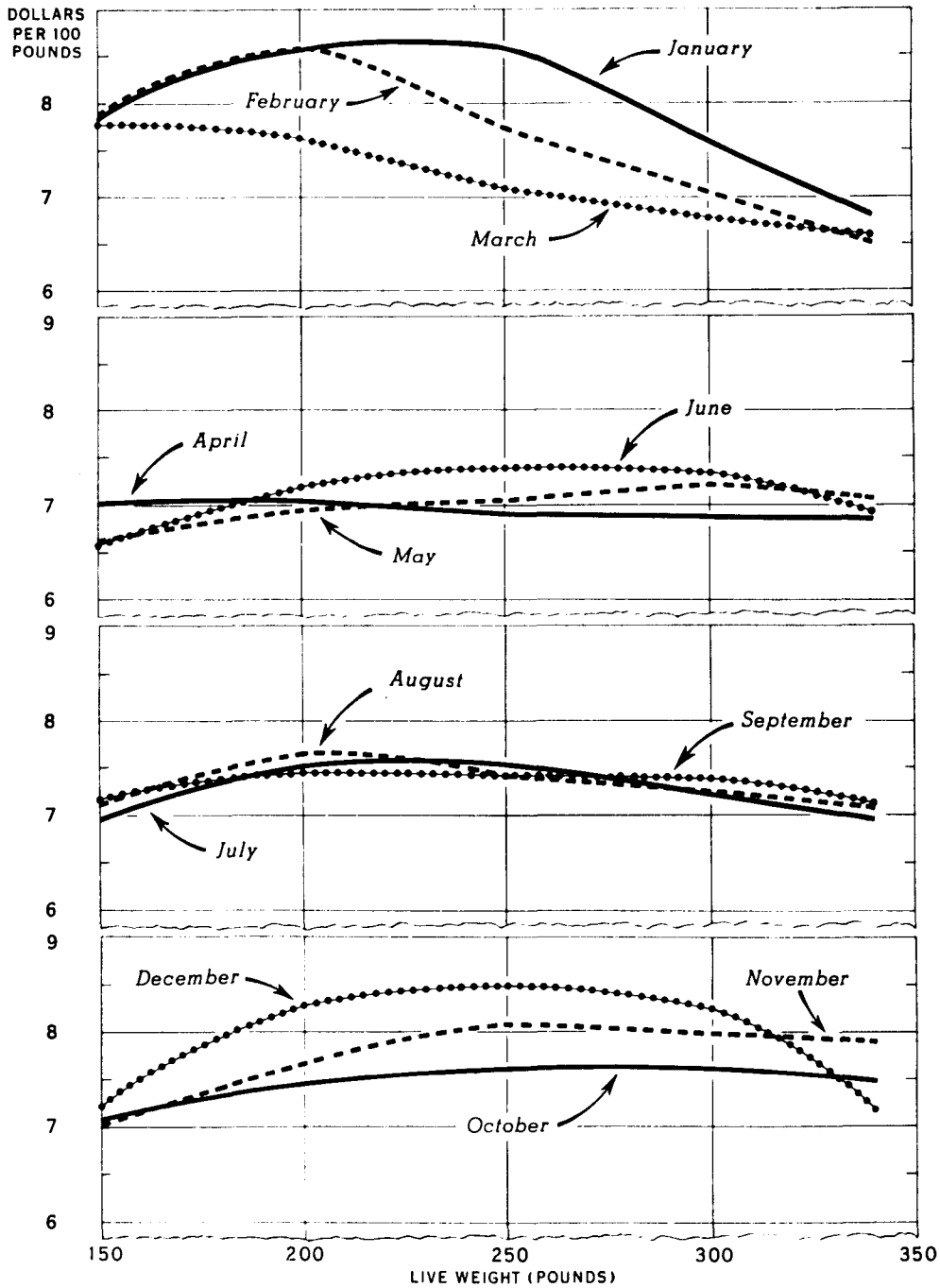


Fig. 5. HOG PRICES BY WEIGHT CLASSES FOR EACH MONTH
1934-41 (ADJUSTED) PRICES, GOOD AND CHOICE BUTCHER HOGS, CHICAGO



LABELS OF CURVES REFER TO MONTH OF FARROWING. PRICES SHOWN FOR EACH WEIGHT ARE THOSE THAT WOULD BE RECEIVED IN THE MONTH AT WHICH THE HOG REACHED THAT WEIGHT BASED ON USUAL PRACTICES, e. g. THE EFFECTIVE PRICES FOR THE APRIL FARROWED PIGS ARE THE OCTOBER PRICE FOR 150 POUNDS, NOVEMBER PRICE FOR 200 POUNDS, DECEMBER PRICE FOR 250 POUNDS, ETC.

Fig. 6. ALTERNATIVE PRICES FOR HOGS MARKETED AT VARIOUS WEIGHTS; BASED ON MONTH OF FARROWING

COMBINATION OF SEASONAL AND DISCOUNT PATTERN, 1934-41 (ADJUSTED) PRICES, GOOD AND CHOICE BUTCHER HOGS, CHICAGO

they are full fed from weaning. Instead of reaching 225 pounds in a little less than 7 months, as in the trials above, hogs are more commonly marketed at 225 pounds about 8 months after farrowing. For all calculations, the hogs will be figured to reach 150 pounds at 6 months and thereafter be full fed until marketed. Full fed hogs on ordinary non-legume pasture may reach the same weights a month earlier, and it is a common goal of farmers to have their pigs almost two months ahead of this schedule, but in recent pre-war years peak marketings have usually occurred in December at an average near 225 pounds while peak farrowings have been in April, 8 months earlier. The adjustment for hogs reaching 150 pounds earlier or later than assumed requires only that the calculations for the succeeding or previous month of farrowing be used if they are finished on full feed. The figures are not the appropriate ones, however, for hogs not finished on full feed.

Some broad generalizations for the average relationships for the (adjusted) 7-year period can be made. The early spring pigs, farrowed in February and March may be marketed much more favorably at 200 pounds than at 250 pounds or heavier weights. The penalty for holding hogs another month after reaching 200 pounds is so great that under usual hog-corn ratios they would not be held. Then the April, May, and June pigs, which include a large part of the spring crop, face a very different market. In general, they may be marketed at a higher price at 250 and 300 than at 200 pounds;[1] here the prices at various marketing weights are real alternatives,

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[1]April has slight discounts for the heavier weights.

the returns from which must be compared with marginal costs in order to determine the most profitable marketing weight (p.34 below).

July represents a transitional month. Pigs farrowed earlier could be kept to heavy weights and sold at higher prices, but the July farrowed pigs while bringing about the same price at 250 as at 200 pounds are discounted for heavier weights. Then the August pigs bring somewhat higher prices at 200 pounds than at heavier weights and the September pigs are only slightly higher at 200 pounds than later. The October pigs have a premium on heavy marketing weights, selling at higher prices each month through 300 pounds, while the November pigs are slightly higher at 250 pounds than at heavier weights. Beginning in December again the discounts for heavier weights appear and in the following months grow larger.

The general principle of comparing marginal cost and marginal revenue

Now that the alternative prices at which a hog can be marketed have been figured, the change in total returns from keeping a hog another month can be calculated and compared with the extra costs of feeding the hog another month. These changes in total returns and costs are usually called marginal revenue and marginal cost.[1]

If the marginal revenue from keeping a hog another month is greater than the marginal cost, then it is profitable to hold the hog to the heavier weight. The marginal revenue can be figured from the alternative

[1]The marginal revenue used here is slightly different from the usual marginal revenue, which is equal to price under competitive conditions. The one here appears to be the analytical equivalent of the usual meaning.

prices (average revenue) for a hog marketed at various weights, which was shown in figure 6. It is the difference between the receipts from selling a hog one month and the receipts from selling the hog a month later. For example, using the top curve in the chart above, a pig farrowed in January will weigh approximately 200 pounds in August and at 1934-41 average (adjusted) prices will return $8.56 per hundredweight or a total of $17.12; but if marketed in September at 250 pounds at the price of $8.58 per hundredweight will return $21.45. The marginal revenue from holding the hog a month is the difference between $21.45 and $17.12 or $4.33. Stated differently, the 50-pound gain increased the value of the hog $4.33, or $8.66 per hundredweight.

Marginal cost can be figured on the basis of the average prices for the same period. Feed is the largest cost of holding hogs to heavier weights, but labor, risk, and interest are not quite negligible. It is estimated that 115 percent of the feed cost will approximate total marginal costs. About 250 feed units are needed for the 50-pound gain in weight. The 250 feed units at $ .73 per bushel (the average Chicago price for corn, 1934-41[1]) times 115 percent equals $3.74, the marginal cost of the 50-pound gain or $7.48 per hundredweight. This marginal cost of $7.48 is directly comparable with the marginal revenue of $8.66 per hundredweight figured above. Thus marketing the hog at 250 instead of 200 pounds is profitable.

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[1]One possible refinement is a seasonal differential for corn prices.

Illustration of marginal cost and marginal revenue comparisons

It was mentioned previously that pigs farrowed in April and May and reaching 200 pounds in November and December did not sell for sharply discounted prices if marketed at heavy weights. A comparison between marginal costs and marginal revenue is needed in order to determine the most profitable marketing weight. Since these months include the peak of the spring farrowings, they are good examples to illustrate the steps in the process.

The marginal costs based on 1934-41 prices of holding hogs to heavier weights are figured in Table 2. Beginning with a hog at 150 pounds, the costs of extra months' feeding are shown for four successive months. For the first month the hog gains 50 pounds, and requires 233 feed units which at $ .73 per bushel (corn price) cost $3.04. Marginal costs are estimated at 115 percent of feed costs, or $3.50 for the 50-pound gain and $7.00 per hundredweight gain. The calculation of the marginal revenue or incremental price for pigs farrowed in April is shown in Table 3 together with the marginal costs.

The incremental price for feeding April pigs from 150 to 200 pounds is $7.08, while the marginal cost of the 50-pound gain is $7.00 per hundredweight. Thus keeping the hogs the extra month nets $ .08 per hundredweight over estimated total costs. Feeding the hogs an additional month would be unprofitable, however, for the next 50-pound gain costs $7.48 and sells for only $6.32 per hundredweight.

Table 2

Marginal Cost of Holding Hogs to Heavier Marketing Weights Based on Average Farm Price Received for Corn 1934-41 of $ .73 per Bushel. Marginal Costs are Figured at 115 Percent of Feed Costs.

Monthly Change in Marketing Weight	Feed Required per Hog for Month	Monthly Feed Cost at $ .73 per Bushel	Monthly Marginal Cost 115% of Feed Cost	Marginal Cost per cwt. Gain
	Feed Units	Dollars	Dollars	Dollars
From 150 to 200 lbs.	233	3.04	3.50	7.00
From 200 to 250 lbs.	249	3.25	3.74	7.48
From 250 to 300 lbs.	270	3.52	4.05	8.10
From 300 to 340 lbs.[1]	237	3.09	3.55	8.88

[1]Note the reduced monthly gain in weight.

Table 3

Calculation of Incremental Price for Pigs Farrowed in April and Comparison with Marginal Cost 1934-41 Prices

Month	Marketing Weight	Price per Hundredweight	Value of Hog	Incremental Price per Hundredweight	Marginal Cost per Hundredweight
	Pounds	Dollars	Dollars	Dollars	Dollars
October	150	7.01	10.52		
November	200	7.03	14.06	7.08	7.00
December	250	6.89	17.22	6.32	7.48
January	300	6.86	20.58	6.72	8.10
February	340	6.85	23.29	6.78	8.88

Similar calculations to those above are shown for pigs farrowed in May in Table 4. For the prices shown, there is little choice between marketing hogs at 200, 250, or 300 pounds, for in this range the change in cost and in returns is about equal.

The calculations of the most profitable marketing weight have been based on the average price relationships for the 7 years (adjusted for secular trend) prior to the price disturbances growing out of the second World War. The farmer needs to know what is going to happen in the months ahead. The best information available on the probable seasonal and discount trends of any given market season must be based in part upon past relationships, as was done in the illustration, tempered by apparent changes in the general economic situation.

The estimation of prices on the cost (feed) side for any given season would be different from the procedure followed above. The average prices of recent years are of much less significance and would form only a minor part of the current situation which has to be analyzed.

In determining the most profitable marketing weight attention has been focused upon growth from weaning to marketing. To obtain complete feed costs of pork production the other part of the cycle of production must be included--the production of weanling pigs, or the breeding herd feed and gain.

Table 4

Calculation of Incremental Price for Pigs Farrowed in May and Comparison with Marginal Cost 1934-41 Prices

Month	Marketing Weight	Price per Hundredweight	Value of Hog	Incremental Price per Hundredweight	Marginal Cost per Hundredweight
	Pounds	Dollars	Dollars	Dollars	Dollars
November	150	6.61	9.92		
December	200	6.93	13.86	7.88	7.00
January	250	7.04	17.60	7.48	7.48
February	300	7.20	21.60	8.00	8.10
March	340	7.05	23.97	5.92	8.88

TOTAL FEED COST OF MARKETABLE PORK PRODUCED

In determining whether hogs should be marketed at 200, 250, or 300 pounds no need was found to consider the breeding herd at all. Once pigs have been weaned, the breeding herd costs are overhead costs that have no influence on the weight at which barrows and gilts should be marketed. For farm planning a year in the future, however, the breeding herd is the same kind of variable as is marketing weight. In considering questions of public policy, breeding herd costs and returns should almost invariably be included.

The Breeding Herd

The feed and gain of the breeding herd have been investigated much less thoroughly and consequently are less accurately established than the feed and gain after weaning. The figures used here are based on (1) cost route and farm business association studies showing breeding herd feed and gain, chiefly the exhaustive summary based on over 10,000 sows prepared by Oscar Steanson[1] and (2) market statistics showing the number of pigs farrowed and saved and the number and weight of sows and butcher hogs marketed. The market statistics more often supplement than overlap the information from the farm management studies; and in the cases where the two differ, the market statistics are used, with adjustments for farm and

[1] Unpublished manuscript, BAE.

local slaughter. The final figures show that 290 feed units are needed per butcher hog marketed, to produce a weanling pig of 35 pounds that will reach market weight; a 20.3 pound live-weight gain for the breeding herd is included. The feed for (1) the boar, (2) the sows not farrowing, (3) the pigs that die before reaching marketing weight, and (4) the farrowing sows from the time they are bred until they are fattened for market is included in the total feed. One-litter and two-litter-a-year systems are figured, then they are combined, and weighted in accordance with their importance in the Corn Belt as a whole. An average of 525 feed units are required to produce 100 pounds live-weight gain of the breeding herd, if the feed to the pigs that die after weaning but before reaching slaughter weight is included, and about 505 feed units per 100 pounds of gain, excluding the feed for pigs that die after weaning. These figures are close to those of Steanson[1] and of Smith, W.W.,[2] which, however, are only semi-independent checks, since reliance was placed on Steanson's estimates while Smith used some of the same data. They are also about the average reported from five farm management studies in Iowa, Illinois, and Indiana,[3] and bear approximately the same ratio to feed after weaning that these five studies show.

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[1] Op. cit.

[2] "Pork Production", Chs. VII, XVI, Macmillan, 1937.

[3] Iowa Bul. 255, 294; Ill. Bul. 390; Indiana Bul. 338, U.S.D.A. Dept. Bul. 1381.

Comparison of Feed per 100 Pounds Pork Produced With Other Reports

The after-weaning feed and gain added to the feed and gain of the breeding herd shows the total feed cost of marketable pork produced. In order to appraise the representativeness of the final figures obtained in this investigation, estimates from other sources are shown below. These estimates fall into two groups, those from several special studies and those from Farm Business Association records in Iowa, Illinois, and Minnesota; both of these sources are based upon the same types of farms--those belonging to farm business associations.

The special studies shown in Table 5 are the best information available for the decade 1920-30, while the Farm Business Association's records Table 6 furnish the most information for 1930-40. The main difference in the two sets of data is that the Business Association records are from the western Corn Belt, mainly Iowa, while the special studies include the eastern Corn Belt as well.

The Iowa studies, 1920-30, of the pounds concentrates per hundredweight gain show some concentration in the range 515 to 525 pounds with 520 pounds as a representative figure. The Iowa Farm Business Association summaries of 1,800 records during the years 1932-39 range from 420 to 470 pounds, averaging 445, which is a drop of 75 pounds, or 15 percent from the previous decade.

Table 5

Summary of Studies of Feed Required per Hundred Pounds of Marketable Pork, 1920-30

Author	Bulletin Number	Location of Farms	Year	Number of Farms	Pounds of Concentrates per 100 Pounds Gain	Remarks
Wilcox	Illinois	Illinois:	1924	34	457	Spring and
Carroll	390	McLain and	1925	37	476	fall litters
Hornung		Woodford Co.	1926	35	487	
Case	Illinois	Illinois:				
Ross	301	Hancock Co.	1913-22	10	485	Exoluding
		Franklin Co.	1913-22	10	464	pasture
		Champaign	1920-25	14	510	
		and Piatt Co.	1921-24	10	558	
Young	Indiana:		1922	44	459	
Steanson	Purdue		1923	45	534	
	Mimeo.		1924	28	425	
	report		1925	30	447	
			1926	33	455	
Hopkins	Iowa 255	Iowa:	1922	59	508	Mostly
		Humboldt Co.	1923	49	525	spring pigs
			1924	51	516	(83 1/2%)
Hopkins	Iowa 294	Iowa:				
		Humboldt Co.	1922-24	159	529	Spring pigs
		Webster Co.	1928-30	113	549	One-and-two-
		Iowa Co.	1925-27	59	518	litter
Hopkins	Iowa 270	Iowa:	1925	21	492	Spring and
		Iowa Co.	1926	21	524	fall litters
			1927	17	543	
Steanson	U.S.D.A.	Iowa:	1921	28	447	One litter
	1381	Henry Co.	1921	16	462	Two litters
		Illinois:	1922	15	461	One litter
		Warren Co.	1922	24	442	Two litters

Table 6

Summary of Farm Business Association Records of Feed Required Per 100 Pounds of Marketable Pork Produced, 1928-42

Year	Illinois		Iowa		Minnesota		Wisconsin	
	Number of Farms	Pounds Concen-trates	Number of Farms	Pounds Concen-trates	Number of Farms	Pounds Concen-trates	Number of Farms	Pounds Concen-trates
1928					173	537		
1929					221	532		
1930					229	527		
1931					197	457		
1932			33	418	197	480		
1933			110	461	165	471		
1934			98	419	167	451		
1935	367	430	71	471	335	512		
1936	419	449	223	469	294	475		
1937	324	430	314	460	136	473		
1938	512	425	498	440	223	480	16	425
1939	499	403	496	427	256	482	87	459
1940	437	416	560	437				
1941	530	420			349	510		
1942	664	450						
Total	3852		2403		2932		103	
Av.		428		443		494		453

The eastern Corn Belt studies, 1920-30, show some concentration in the range 450-460 pounds concentrates per hundredweight gain with 455 a representative figure. The only figures available for the following decade are from Illinois. Approximately 500 farms averaged 425 pounds of concentrates during the years 1935-42.[1]

It will be remembered that comparisons of the record-keeping farms with all farms invariably show these farmers to be somewhat above the average for all farms in most respects,[2] including presumably in obtaining pork production from any given feed supply. The detailed estimates of Jennings,[3] however, of all feed disappearance per hundredweight gain are 443 pounds for 1929-33 and 429 pounds for 1938-40. The figure used in this study is 414 pounds concentrates, but comparisons based on feed units are more appropriate than those using pounds of concentrates. The rations in the experiments used in this study contain more feed units per pound of concentrates and normally cost more per pound, but about the same per feed unit. The rations fed in the Iowa Farm Business Associations are less balanced than those reported in Illinois Associations which in turn are inferior to those in the 12 experiments used here. They have been compared on a pound basis because in some instances the composition of the rations was not available, but enough samples are reported to make possible average feed unit values.

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[1]Records were omitted from farms producing less than 10,000 pounds of pork annually.

[2]Hopkins, J.A. Statistical Comparisons of Record-Keeping Farms and a Random Sample of Iowa Farms for 1939. Iowa Agr. Expt. Sta. Res. Bul. 308, 1942.

[3]U.S.D.A. Circ. 670, 1943.

The feeding value of tankage, soybean meal, and other supplements will vary with changes in their proportion in the ration, but the values used by Jennings[1] will make more comparable in cost and in nutritional value rations varying somewhat in composition from that of the average for the Corn Belt in recent years. The various estimates of feed requirements are shown in Table 7 in pounds and in feed units. Notice that the present study is slightly lower than the others in pounds concentrates, but a little higher in feed units. This higher feed-unit value of the rations in the 12 experiments is partly due to these trials being conducted in dry lot while the other figures are based on pasture feeding. The feed-unit figures are considered to be more representative of Corn Belt conditions with ordinary non-legume pasture.

Pork Production and the National Food Supply

The after-weaning data were shown to be useful from the viewpoint of the farmer in choosing the most profitable marketing weight. The inclusion of the breeding herd made possible the relation of total feed consumed to pork produced. This provided a partial basis for comparing hogs with other enterprises. Now the viewpoint will be shifted to that of the national food supply; interest will center on dressing percentages and composition of the carcass--considerations which concern the farmer as a producer only indirectly through their relation to discounts on hogs marketed unfinished

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[1]Ibid.

Table 7

Representative Feed Requirements per 100 Pounds of Marketable Pork Produced; Comparison of Two Bases

	Pounds Concentrates	Feed Units
Iowa Farm Business Association 1932-38	445	460
Illinois: Champaign and Piatt Counties 1935-41	420	450
Jennings 1938-40	428	435
Present Study	414	468

or at heavy weights. Even this effect is a little vague because of the imperfect grading that is possible on a liveweight basis.

As hogs are marketed at heavier weights, four changes take place, which are the principal variables in studying the efficiency of hogs in converting feed into food:

1. The feed required per pound gain in live-weight increases.
2. The dressing percentage increases.
3. The proportion of edible to inedible product increases.
4. The proportion of fat increases and of protein decreases.

Much of what follows will be concerned with the relationship between these four changes. The first one, already developed, indicates that hogs become less efficient converters of feed into live weight, but the increase in the dressing percentage and in the proportion of edible product operates in the opposite direction, while finally the decreasing percentage of protein associated with lean meat, vitamins and minerals, makes the increasing edible product vary in value per pound.

INPUT-OUTPUT RELATIONSHIPS FOR PORK AND LARD

In a previous section it was mentioned that the feed-live-weight relationship is not the significant diminishing returns problem of pork production. Now it is possible to begin a three-step analysis which the writer submits as the most important input-output problem of pork and lard production.

In the first step, output per unit of input is compared on three bases--live weight, dressed carcass, and edible product (pork and lard). Measurement of output in terms of edible product is a refinement over the live-weight and dressed-carcass bases but it is not definitive. The composition of the carcass must be determined. Three ways of measuring output in terms of pork and lard are compared. One of these, the standardized pork method is shown to be valid for comparing the carcasses of hogs of different slaughter weights.

In the second step, "joint output" of standardized pork and residual lard are measured on both average and additional bases. Changes in the proportions of standardized pork and residual lard can be made by changes in marketing weight and in the number of pigs farrowed.

In the third step, the possibility of change in proportions of pork and lard produced is utilized to determine the marginal feed cost of standardized pork, independent of changes in residual lard. In an analogous manner, the marginal feed cost of residual lard is determined. Then, the effect on the marginal costs of incomplete accounting for

breeding herd feed and gain is shown.

Finally, the marginal costs are examined for plausibility, and in some examples the conditions under which the costs are valid are explored. One application of the marginal concepts is made.

The First Step--Output of Live Weight, Dressed Weight, and Edible Product

The relation between feed and live weight, which is of strategic importance to the farmer in determining marketing weight, has already been explored, but the average relationship has not been shown previously.

The measurement of output in terms of the whole hog--live, dressed, and edible basis--is basic to the determination of output of pork and of lard. In figure 7 are shown the average outputs measured in these three ways and also the increase in each from additional feed based on average Corn Belt conditions. Output per feed unit is measured on the vertical axis while the live weight of the butcher hog is shown on the horizontal axis. The solid curves show the average output per unit of feed and the dotted lines show the increase in output for additional feed for the range of live weight in which pigs are ordinarily marketed. The largest live-weight pork output per 100 feed units is in the 150 to 200 pound marketing range, but production decreases only 2.5 percent in efficiency from 175 pounds to 275 pounds. On the marginal basis, the decrease in the same range is 14 percent.

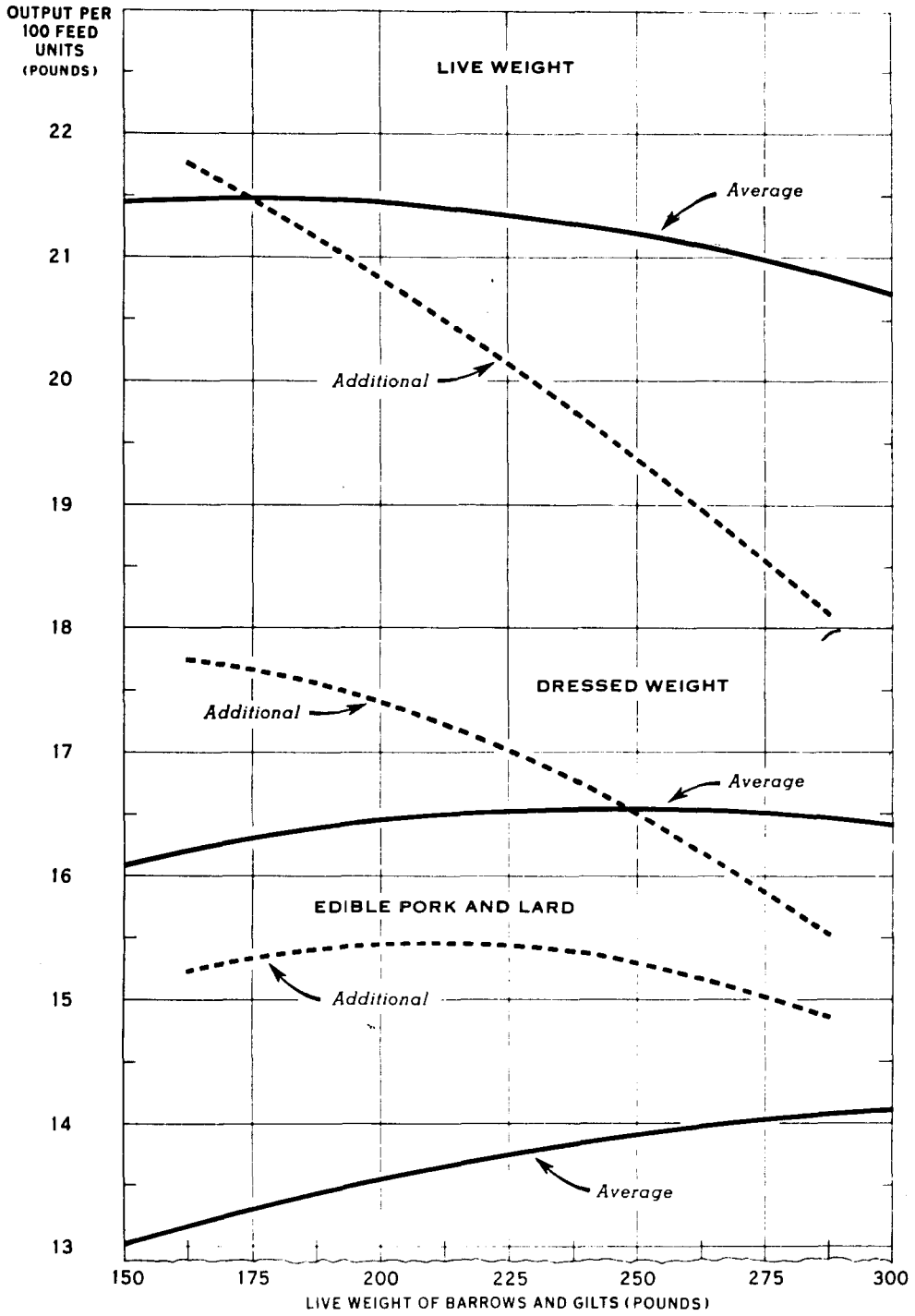

Fig. 7. LIVE WEIGHT, DRESSED WEIGHT, AND EDIBLE PORK AND LARD PRODUCTION PER 100 FEED UNITS FOR HOGS MARKETED AT VARIOUS WEIGHTS

CORN BELT CONDITIONS; INCLUDES BREEDING HERD

The maximum output of dressed carcass per 100 feed units is obtained in the marketing range 225 to 275 pounds--about 75 pounds heavier than the peak output measured on a live-weight basis. While gains above 175 pounds require more feed than previous gains, the decrease in efficiency of gain is so gradual that it is more than offset by the increased dressing percentage of heavier hogs up to a weight of about 250 pounds. Carcass produced per 100 feed units increases about one percent between 200 and 250 pounds marketing weight and decreases about one percent between 250 and 300 pounds. The decrease in the marginal output of carcass between 250 and 300 pounds, however, amounts to 7 percent.

The output of edible product (standardized pork plus lard) per 100 feed units increases throughout the range of data shown although at a decreasing rate. The increase in output per feed unit is less than one percent between 250 and 275 pounds, and apparently only half as much for the next 25-pound increase in weight. At 275 pounds, however, which is the upper weight limit of the composition data observations, the marginal output, though declining, is about 6 percent above the average. The explanation of this (rather surprising) relationship is best made in reference to the four principal variables referred to above.

1. The feed required per pound gain is increasing directly with marketing weight as is well known, but the rate of increase is rather slow, particularly if feed is measured in feed units, which are more appropriate than pounds of feed, the usual measure.

2. The increase in the dressing percentage, and
3. The higher proportion of edible to inedible product taken together are larger than the decline in gain per feed unit. The net result of these three variables is that edible product per feed unit increases up to 275 pounds. This result, however, is only an intermediate one and should not be used to determine the most efficient marketing weight from the public's standpoint, for this depends upon
4. The rather rapidly changing composition of the hog (with increase in marketing weight), which will now be explored.

Composition of the carcass

As the hog increases in marketing weight the percentage of both the intramuscular or invisible fat and the visible fat increases while the percentage of protein and of water in the carcass declines. Since both meat and lard are obtained from hogs, expressing output in these terms seems desirable. Before attempting this, however, the relation between feed and output measured in physical terms is shown in figure 8. Both the feed and the gain of the breeding herd are included.

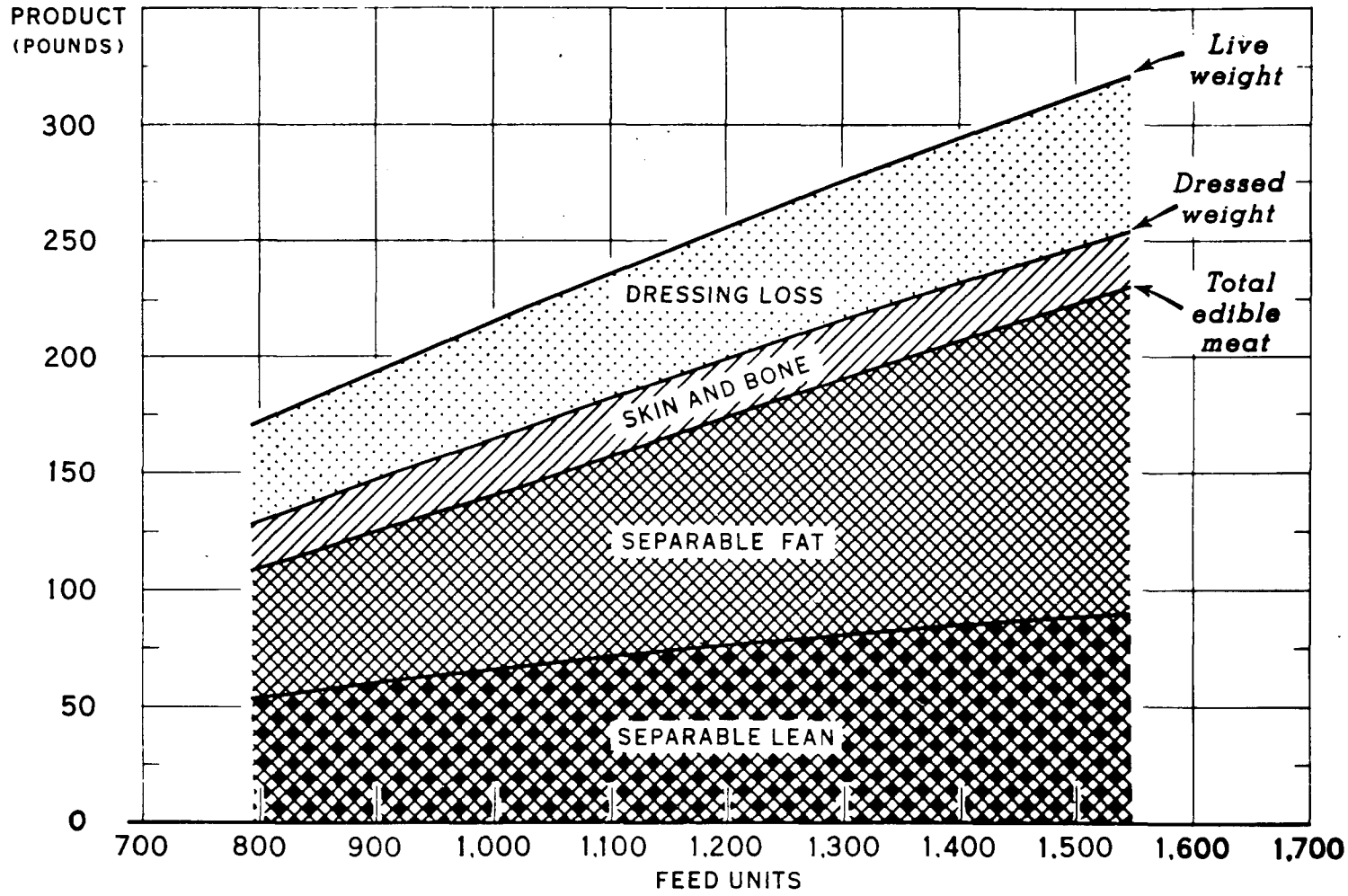

Fig. 8. OUTPUT AS RELATED TO INPUT, PER HOG BASIS

CORN BELT CONDITIONS; INCLUDES BREEDING HERD

Three ways of measuring output of pork and lard

Measuring the output of pork and lard is complicated by the varying composition of pork from hogs of different weights and from hogs of the same weight marketed at different times. The first point is obvious enough--that cuts from heavy hogs will be fatter and usually less desirable; the second is no less important--that packers vary the relative yields of pork and of lard with changes in demand, by changing the composition of the pork as explained below.

Standardized cutting. An attempt to measure not only pork yields but also yields of the various cuts by a method that is not influenced by price changes is the standardized cutting technique adopted by the Bureau of Animal Industry at Beltsville. The excellent results obtained[1] are also important for figuring output on other bases.[2] Two limitations of this method are that it is neither the way hogs are cut up by commercial packers nor are the cuts from different weight hogs of the same composition. No one method can be both of these, of course, but the results of each are shown below.

Packer practice. Packers trim carcasses to fit the current demand, i.e., they attempt to cut the carcasses coming to market in such a way that the resulting pork cuts and lard will sell for the greatest value allowing for costs involved in extra trimming, processing, etc. It may be rather surprising that in ordinary packing practice the

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[1]See Yearbook of Agriculture, 1939, p. 460 ff.

[2]Page 55 below.

lard yield (percent) is lower from heavy hogs than from light ones (figure 9). Some fat cuts such as backs, plates, and jowls are normally rendered into lard from hogs in the 180 to 220 pound weights, but are sold as pork cuts (fat backs, clear plates, and bacon squares) from heavy hogs. Thus the "pork" obtained from heavy hogs is considerably fatter than from light hogs and is not comparable either nutritionally or from the standpoint of demand. In some instances the demand for the cuts is so radically different from light and from heavy hogs that the two products are sold to fairly distinct groups of customers--e.g., breakfast bacon from fancy sweet pickled bellies on light hogs and "sidemeat" or salt pork from dry salted bellies on heavy hogs are not very close substitutes for each other.

There are two reasons, then, why Packer Practice is an unusable measure of pork and lard production. The first is that packers are continually changing the way that they trim hogs of the same weight and finish with changes on both the demand and the supply side. The second reason is that if packers always trimmed similar hogs in the same way, comparison of meat from light and heavy hogs would be inconclusive because of the difference in composition.

Standardized pork.[1] A third method of comparing pork and lard yield from hogs of varying slaughter weights is to trim the fatter cuts from the heavier hogs more closely than the leaner cuts from the lighter hogs so as

[1]This method was suggested by John W. Klein, formerly of the BAE.

to obtain cuts of approximately standard composition regardless of the weight of the hog. The extra fat trimmings would be rendered into lard. This would make the lard yield increase directly with marketing weight. Beginning with the cuts obtained by the standardized cutting process, using the results of careful tests of the Bureau of Animal Industry, the composition of each cut can be approximately standardized for hogs weighing from 175 to 275 pounds by trimming the fat on them more or less closely as needed. The result is pork of a given composition from various weights of hogs which is termed "standardized pork." The remaining fat trimmings are figured on the basis of the fat contained, i.e., a rendered basis, and is called "residual fat, lard equivalent."

Standardized pork and residual lard are based upon the edible portion of the carcass from a 225-pound butcher hog. They differ from the dressed carcass by including edible offal but excluding bone and skin. The standardized pork and residual lard from a 225-pound hog will weigh about 80 percent as much as the dressed carcass. The 13 percent protein and 42 percent fat in the standardized pork are about the same as Chatfield and Adams' figures on the proximate composition of the edible portion of medium carcasses. In other words a pound of standardized pork is equal to one pound of the edible meat (exoluding skin and bone) from a medium carcass, and is equal to 1.1 pounds of meat as purchased at the store.[1]

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[1]Except for a slight adjustment for edible offal. "Proximate Composition of American Food Materials," U.S.D.A. Circ. No. 549, 1940.

While it is assumed that each cut is handled in a standard way, the validity of standardized pork as a measure of the nutritional value of pork and lard does not depend upon a carcass being actually cut in the prescribed manner. It is not essential that a fat cut, e.g., clear plate, be rendered but merely that it be given its lard equivalent value. If clear plates are more valuable as a pork cut than if rendered into lard, the evaluation of the edible protein and edible fat in it is valid even though it is not rendered. One result of this calculation is that the "residual fat, lard equivalent" overstates the visible fat production, but since fat cuts are used in part for the same purposes (e.g., seasoning) as visible fat, the failure to qualify as a visible fat may not be serious as far as the fat supply is concerned and appear as a problem only in the artificial classification of fats which includes only the visible supply. From a nutritional standpoint, plates and backs are of about the same value as pork cuts or as lard and cracklings, except for any difference in waste. Similarly the use of standardized pork and residual fat, lard equivalent is nutritionally valid for measuring the other cuts from various weight hogs even though this method of cutting is not followed.[1]

For this reason, it is legitimate and more accurate to assume complete standardization for comparing hogs of different weights even though only an approximation is feasible in practice. Care is taken that the edible fat and edible protein is accurately reflected in the extensive use of standardized pork that is made throughout the study. The use of this concept is

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[1]It will not, of course, reflect consumer's preferences for particular size cuts.

based on the belief that this is the most appropriate measure available for comparing hogs of different weights.

The three methods for measuring output of pork and lard that have been described are shown together on the same scale in figure 9.

The Second Step--"Joint Output" of Pork and Lard Separable Fat and Lean

In figure 10 is shown the joint output of standardized pork and of residual fat per 100 feed units along with the separable lean and separable fat output for hogs of various marketing weights. The separable fat and separable lean as previously explained are physical determinations made by separating the lean or the muscle meat from the fat with a knife--probably most easily explained by saying--in the fashion of Jack Spratt and his wife. This classification is an intermediate step in determining standardized pork and residual fat; it is shown here as an aid to the understanding of the standardization of pork.

The output of pork and lard is called joint output because for each output of standardized pork an output of residual lard is produced jointly. Thus, for hogs marketed at 200 pounds, 10.58 pounds of standardized pork are obtained per 100 feed units, but this is in addition to 2.96 pounds of residual fat which are obtained from the same 100 feed units. Standardized pork per 100 feed units decreases with marketing weight while residual lard increases. The increase in lard is about twice as great as the decrease in pork near 200 pounds marketing weight, but it is only 20 percent greater near 275 pounds. This is true in spite of the fact that the rate of

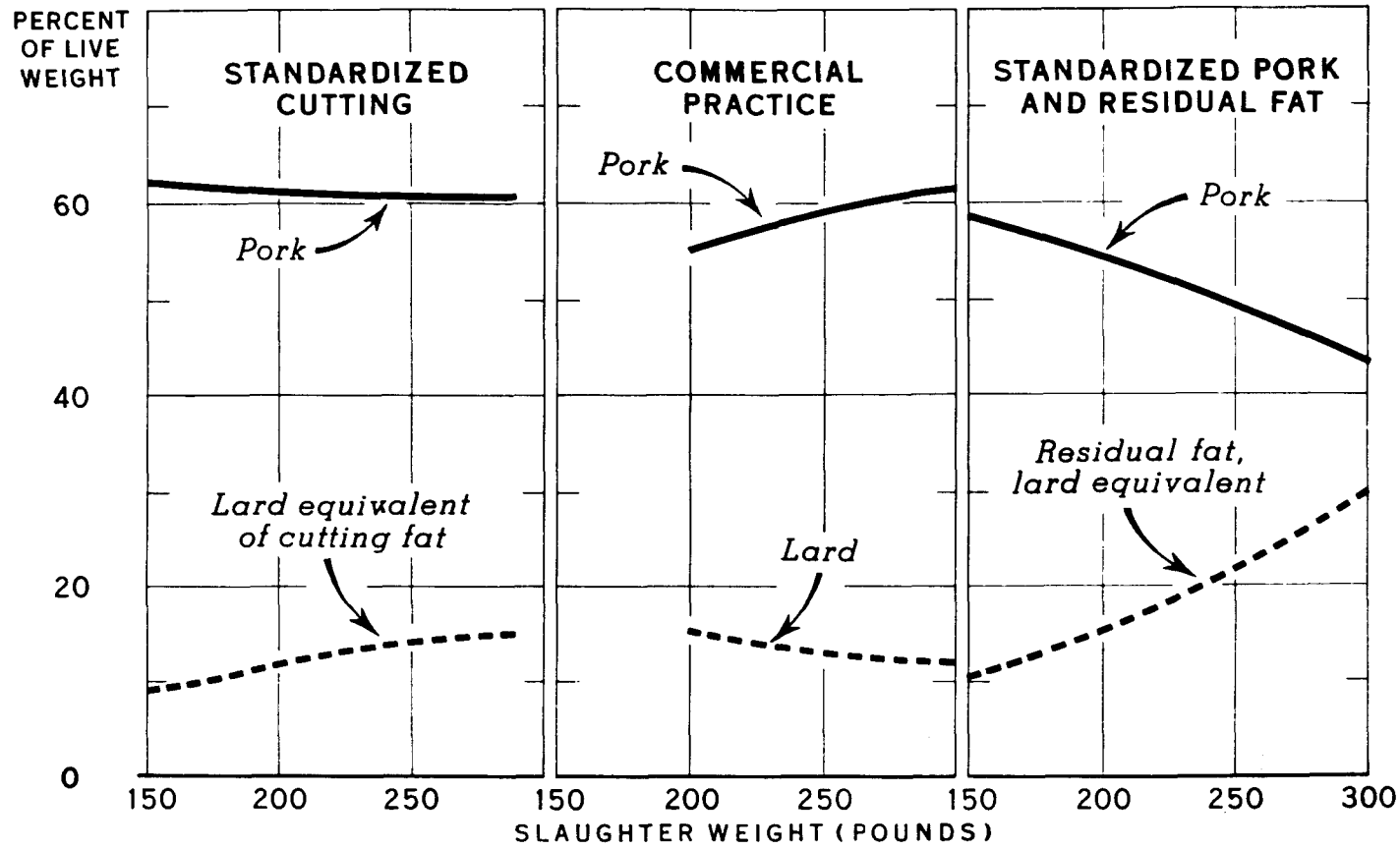

Fig. 9. PORK AND LARD YIELD FROM THREE WAYS OF CUTTING THE CARCASS

USING A STANDARDIZED CUTTING PROCEDURE, LARD YIELD INCREASES DIRECTLY WITH SLAUGHTER WEIGHT, BUT THE COMMERCIAL PRACTICE OBTAINS A HIGHER LARD YIELD FROM LIGHT HOGS THAN FROM HEAVY HOGS. IF THE CARCASS IS TRIMMED TO OBTAIN PORK OF STANDARD COMPOSITION AT ALL WEIGHTS, LARD YIELD INCREASES SHARPLY AT HIGHER SLAUGHTER WEIGHTS

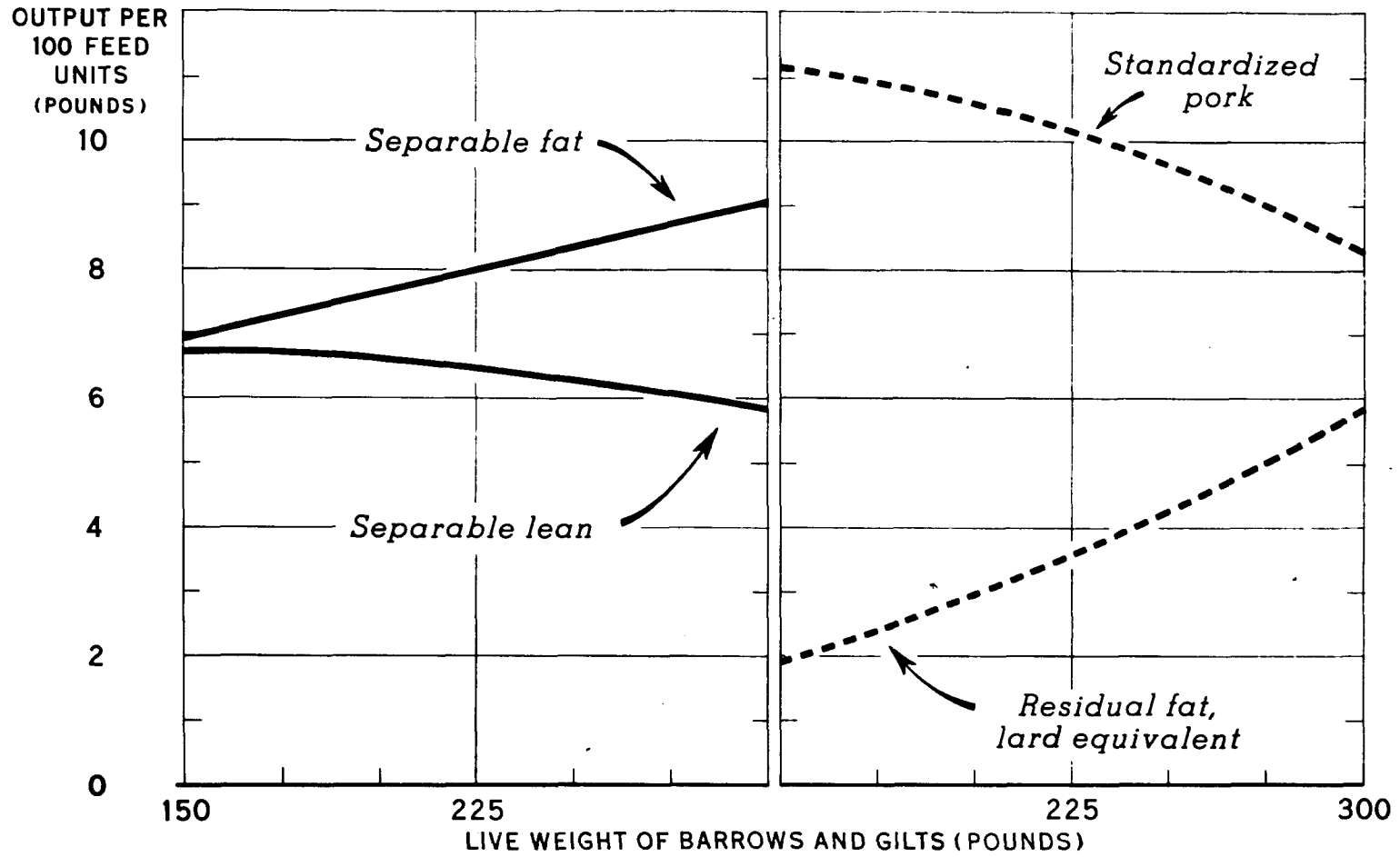

Fig. 10. TWO WAYS OF MEASURING OUTPUT PER 100 FEED UNITS FOR THE USUAL SLAUGHTER WEIGHTS
CORN BELT CONDITIONS; INCLUDES BREEDING HERD

increase in lard production per 100 feed units with increase in marketing weight is about 50 percent greater at 275 pounds than at 200 pounds, for the decline in pork production per 100 feed units is twice as great at 275 as at 200 pounds marketing weight.

In figure 11 the average and the additional output of standardized pork and residual lard per 100 feed units are compared. For barrows and gilts marketed at 200 pounds, 78 percent of the total edible product is standardized pork, but only half of the additional product is pork. At 250 pounds almost 70 percent of the total edible product is standardized pork but at this weight standardized pork comprises only one-fourth of the additional product.

The additional curves should not be confused with the true marginal output curves which are developed in the next section. The curves here show the joint output of standardized pork and lard from 100 additional feed units at various weights but do not show the marginal output of standardized pork and of lard per 100 feed units, and thus cannot be inverted to show marginal costs.

The possibility of obtaining pork and lard in various proportions, however, is of strategic importance, for by a well known theorem in economics, if the proportions in which two products are produced can be varied, the marginal costs of each can be determined. The varying of the proportions between pork and lard is the next step.

Changes that can be made in standardized pork and lard equivalent production from a given quantity of feed for a marketing year beginning

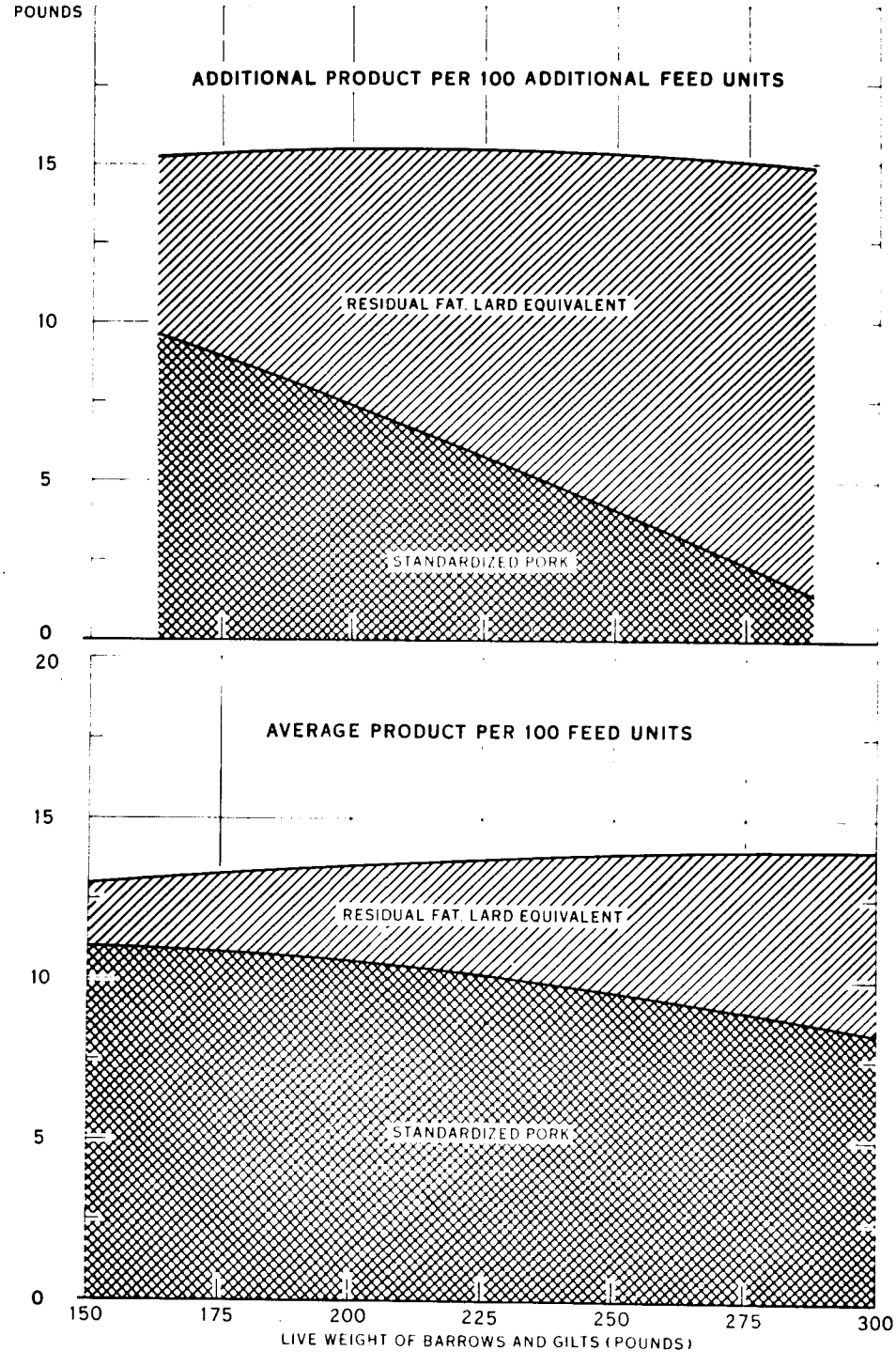

Fig. 11. OUTPUT OF STANDARDIZED PORK AND RESIDUAL FAT PER 100 FEED UNITS FOR VARIOUS LIVE WEIGHTS
CORN BELT CONDITIONS; INCLUDES BREEDING HERD

12 months in the future are rather large. If the price situation is more favorable for standardized pork than for fat this would call for an increase in the number of sows farrowing and a reduction in marketing weight. This adjustment would increase pork and decrease lard equivalent production. If the demand for fat is favorable relative to pork, e.g., if the export demand for lard is active, a decrease in farrowings and an increase in marketing weights will expand fat at the expense of pork. In the absence of support prices, inability to predict the demand-supply situation for a year in the future inhibits adjustment on farms to the price situation. This uncertainty, however, does not deny the possibility of rather large shifts in the relative quantities of standardized pork and fat produced. A system of forward pricing which would reduce the uncertainty would make possible more rapid shifts on farms than ordinarily occur. Experience in 1942-45 with price guaranties for hogs suggests that the reduction of uncertainty is a powerful force in bringing about shifts of this type.

Rather sensitive shifts in pork and lard production with changes in the price situation have been so characteristic that ratios of corn and hog prices have been regarded as crucial in regulating production, despite uncertainty of price changes. In case some of the uncertainty is removed by forward prices, it is especially important to survey the shifts that are feasible. The whole process of shifts in standardized pork and residual fat brought about by changes in marketing weights and hog numbers cannot be shown on a two dimensional chart, but in figures 12 and 13 below are two compromise presentations. In figure 12 the standardized pork and residual fat (vertical axis) that can be produced from 88 billion feed units are

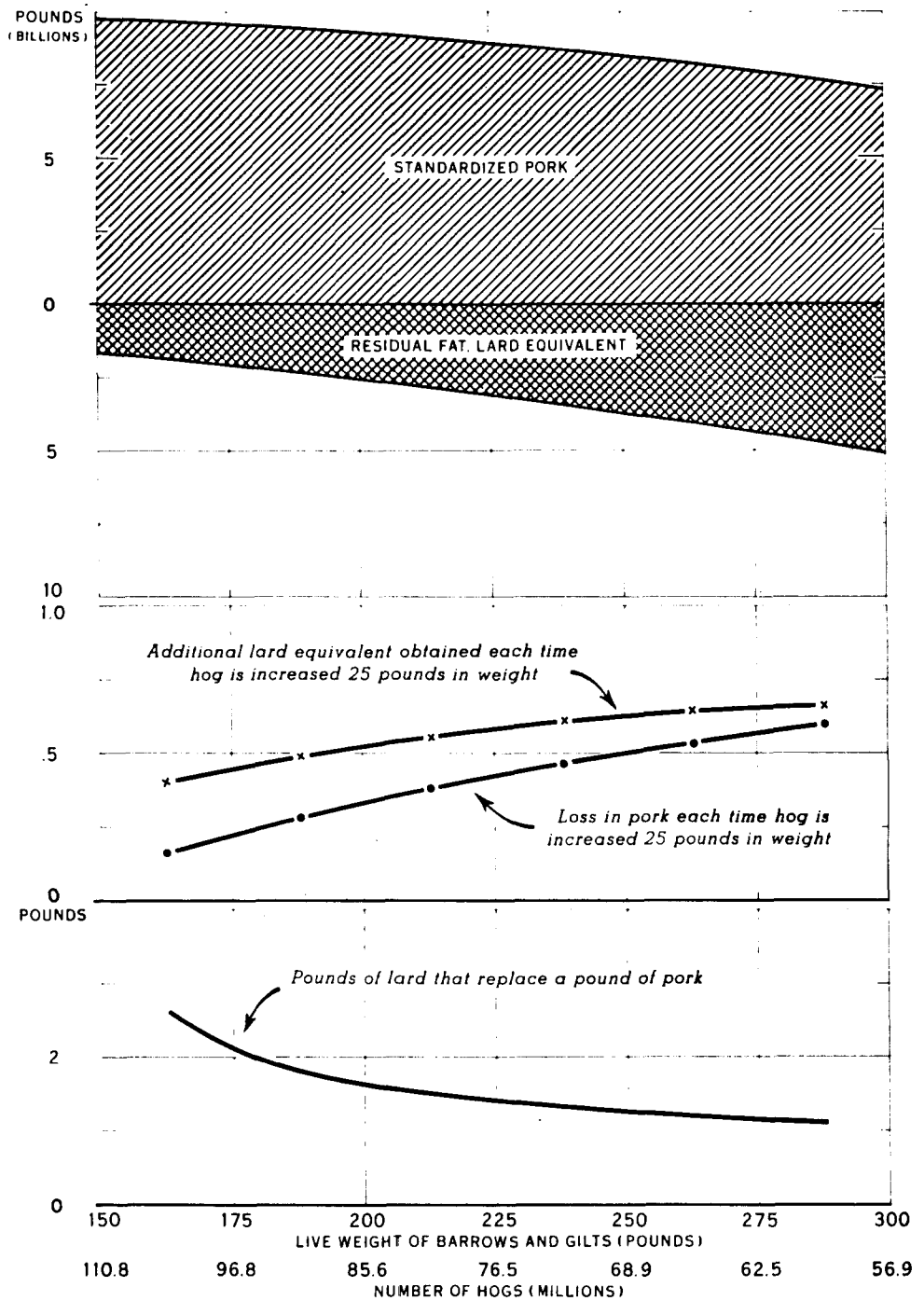

Fig. 12. ALTERNATIVE QUANTITIES OF STANDARDIZED PORK AND RESIDUAL FAT OBTAINED FROM THE NUMBER OF HOGS OF VARIOUS MARKETING WEIGHTS THAT CAN BE PRODUCED WITH 88 BILLION FEED UNITS (1935-39 AVERAGE)
CORN BELT CONDITIONS; INCLUDES BREEDING HERD

shown for 25 pound intervals in marketing weight (horizontal axis) for barrows and gilts varying from 150 to 300 pounds. The number of hogs that would be marketed at each weight also is shown on the horizontal axis. The 88 billion feed units is an estimate of the amount of feed used by hogs in the years 1938-40[1] and is a current estimate of the feed available for hogs in 1944-45. Marginal outputs would be the same regardless of what fixed supply of feed was assumed.

In the middle of figure 12 is shown the change in standardized pork and in lard production from each shift of 25 pounds in average marketing weight. The increase in lard is greater than the loss in pork for all changes in weight, but, as shown in the bottom line, is more than twice as great between 150 and 200 pounds but only 10 percent greater between 275 and 300 pounds. In figure 13 the possible shifts in standardized pork and residual fat are shown in a way which makes possible more precision in measuring the effect of changes in marketing weights. Production of pork is shown on the vertical axis and of fat, lard basis on the horizontal axis. The curve shows the variations in each that are obtained by shifting marketing weights. Marketing weights are indicated but the number of pigs is not shown. At the upper left section of the curve where pork production is largest and the lard yield is least, weights are low and hog numbers high. Moving along the curve to the right and downward pork declines and lard increases. Numbers gradually decrease and weights increase. The curve shows not only that fat production can be increased at the expense of

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[1]Jennings, R. D. Op. cit.

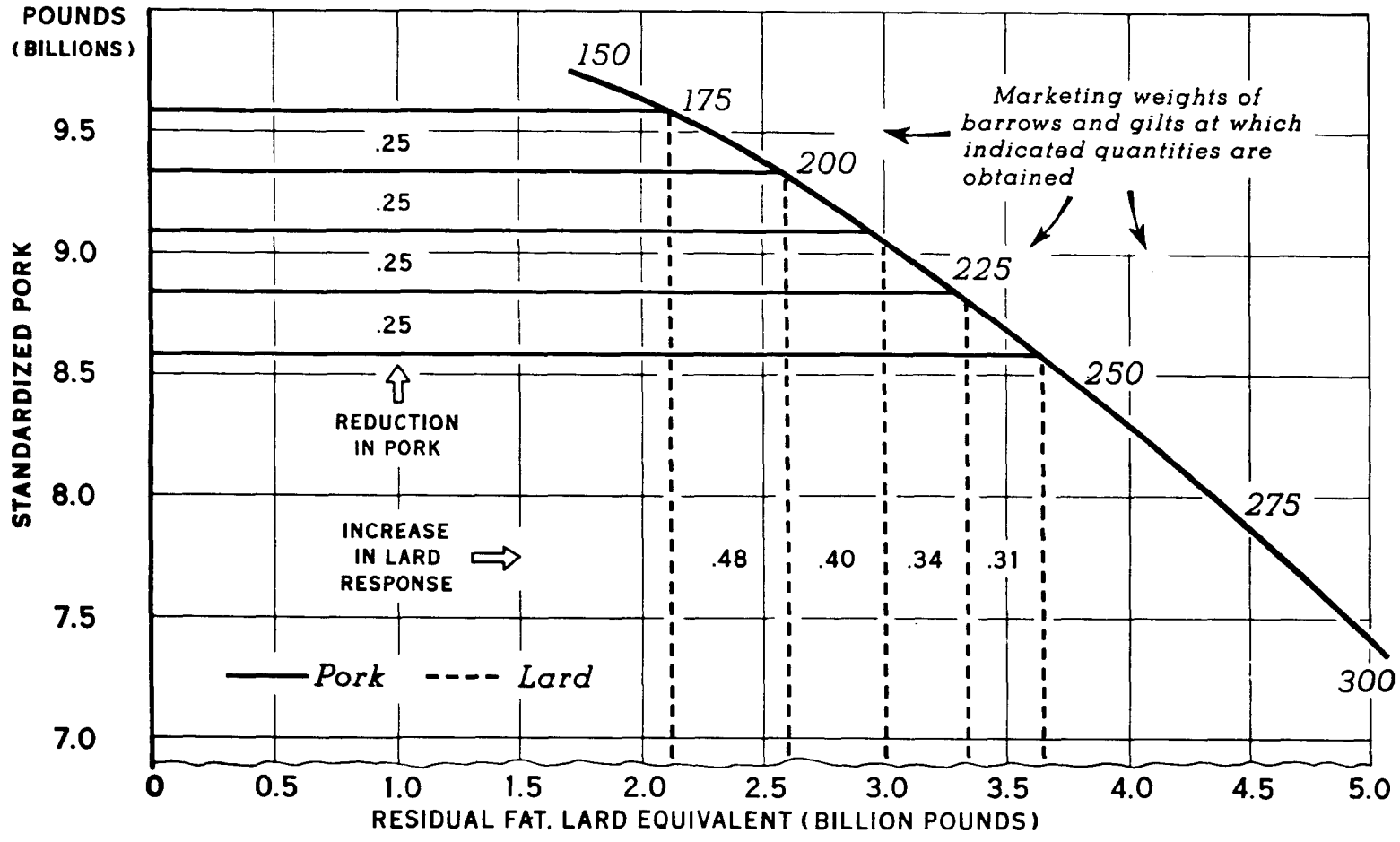

Fig. 13. ALTERNATIVE QUANTITIES OF STANDARDIZED PORK AND RESIDUAL FAT THAT CAN BE OBTAINED FROM 88 BILLION FEED UNITS

PRODUCTION INDIFFERENCE CURVE SHOWING INCREASES IN LARD EQUIVALENT PRODUCTION ACCOMPANYING SUCCESSIVE EQUAL REDUCTIONS IN STANDARDIZED PORK

pork for a given input of feed by increasing weights and decreasing farrowings, but it shows by how much pork must be reduced to get increases in lard, which may be termed the pork cost of lard.

To determine the pork cost of lard, the standardized pork production from light weight hogs, say 175 pounds, is calculated and by successive steps the standardized pork production is reduced and the change in lard yield that can be obtained observed. If hogs are marketed at about 175 pounds, 9.58 billion pounds of pork and 2.12 billion pounds of lard are produced. The procedure followed will be to see the effect on lard production of successive reductions in pork production. This will be accomplished by reducing hog numbers and increasing marketing weights. If pork production is reduced 250 million pounds, lard can be expanded by 480 million pounds. Thus a pound of lard can be secured by a reduction of .52 pounds of pork in this marketing range. Marketing weights are increased almost 25 pounds by this shift to 200 pounds and hog numbers are reduced by 11 million head as explained before. If pork production is reduced another 250 million pounds, lard can be increased by 400 million pounds. From the chart it can be seen that each successive equal reduction in pork makes possible smaller expansions of lard--340 million pounds of lard for the third pork reduction of 250 million pounds, and 310 million pounds for the fourth, and so on. As hogs increase in marketing weight, the amount of lard that can be secured from a given reduction in pork decreases or, to put it differently, the pork cost of lard increases with increase in marketing weight. Retracing the steps taken on the chart, if

standardized pork is increased by 250 million pounds, each successive increase in pork is accompanied by a larger reduction in lard. Thus, a given increase in pork production requires a greater reduction in lard yield in the case of light weight hogs than for the heavier ones. The marginal cost of pork, then, in terms of lard decreases with increase in marketing weights. These results are preliminary to the determination of the marginal feed costs of pork and lard for hogs marketed at various weights, which is the next step. While feed is assumed to be fixed in these calculations, this is no limitation of the results, but merely a simplification of the analysis; if the possibilities of a given quantity of feed are explored, it is a simple step to calculate the effect of changes in the feed supply.

The Third Step--Input-Output for Standardized Pork and Residual Lard

The feasibility of simultaneous shifts in number of pigs farrowed and in marketing weights makes possible the use of the standard Marshallian[1] treatment of input-output measurement and marginal cost determination for "joint products." Pork and lard are joint products whose proportions can be--and are in practice--varied within rather wide limits. The classical examples of "beef and hides" and "mutton and wool" are extremely awkward

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[1]Marshall, A. Principles of Economics, 8th edition, p. 390. Appendix Mathematical Note XIX, p. 854.

compared with pork and lard.

In the preceding section, increases in lard at the expense of pork were illustrated for a given feed supply. If changes in feed are introduced, either standardized pork or residual lard may be maintained at any given level while the other (pork or lard) varies.

Figure 14 is similar to figure 13 except that instead of a curve for one quantity of feed, four curves for four quantities of feed are shown. As before each of the heavy lines shows alternative combinations of pork and lard that can be produced for each of the feed quantities. The radial dotted line cutting across these heavy lines connect outputs obtained from equal marketing weights. To obtain the marginal feed cost of lard, it is necessary to hold pork production constant. Then the lard production can be increased and the increase in feed that is needed to obtain a unit increase in lard is the feed cost of this unit of lard. In figure 14 this is shown by beginning with production of 9.68 billion pounds of standardized pork and 2.12 billion pounds of (residual) lard obtained from 88 billion feed units fed to 96.8 million hogs marketed at 175 pounds. Moving horizontally from Curve I to Curve II (instead of along Curve I as was done in figure 13) pork production is unchanged while lard yield is increased from 2.12 to 3.01 billion pounds or an increase of .89 billion pounds at an increase in feed of 4 billion units which is the difference between each of the feed curves, by construction. The marginal

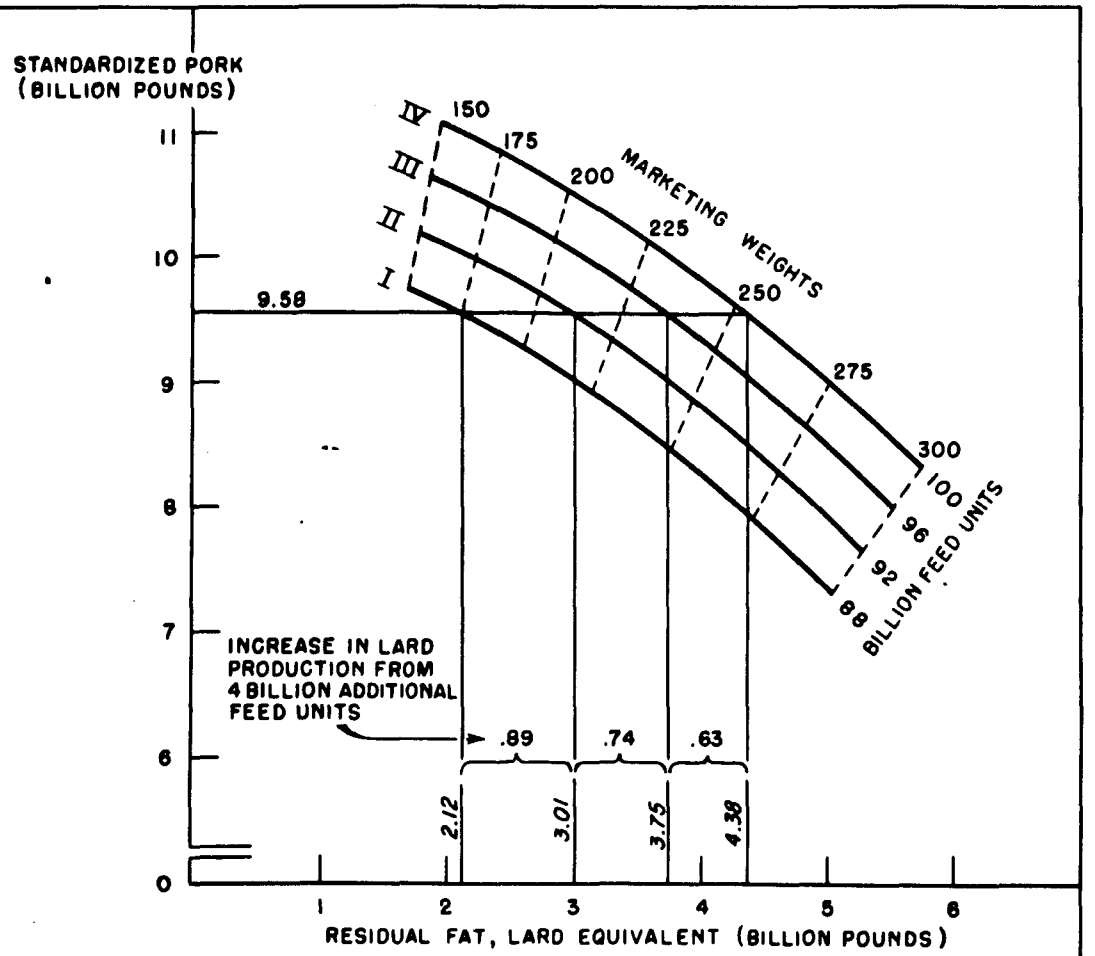

FIG. 14. MARGINAL FEED COST OF INCREASES IN TOTAL LARD EQUIVALENT PRODUCTION FOR THREE INCREASES IN MARKETING WEIGHT USING EQUAL CHANGES IN FEED CONSUMPTION.

As marketing weight is increased, the marginal feed cost of lard rises. For the increase in weight from 175 to 210 pounds, 4 billion additional feed units increase lard by .89 billion pounds or at a marginal cost of 4.49 feed units per pound of lard. For the 2nd increase in marketing weight, the marginal cost is 4 billion divided by .74 or 5.41 feed units. For the 3rd increase in marketing weight, the marginal cost of lard rises to 6.35 feed units.

cost of this increased lard then is 4 billion feed units divided by .89 billion pounds of lard, or 4.49 feed units. This same procedure can be repeated by moving horizontally from Curve II to Curve III, and then from Curve III to Curve IV. While pork production is unchanged lard production increases from 3.01 to 3.75 and then to 4.38 billion pounds. Each move is toward a higher marketing weight for hogs. Note that the equal increases in feed bring smaller increases in lard as the weight of hogs increases. Thus the marginal feed cost of lard increases with increase in marketing weight.

Curves similar to those in the previous figure are repeated in figure 15 to show the marginal cost of standardized pork. The principal difference is that to get equivalent or appropriate changes in pork production it is necessary to increase feed more than previously. Beginning with a marketing weight of 225 pounds, three equal increases of feed are shown. If marketing weights are reduced and the number of pigs marketed is increased so that lard production remains unchanged, as shown in the figure, the successive increases in pork for each 20 billion feed unit increase are 2.53, 2.46, and 2.36 billion pounds. Thus with decreases in marketing weights, the marginal feed cost of pork increases, although very gradually.

Since the graphic method of determination of marginal cost is not exact and since it is an advantage to have the marginal costs between definite marketing weights, they are determined for 25-pound intervals in marketing weight of the butcher pig in the table below (Table 8).

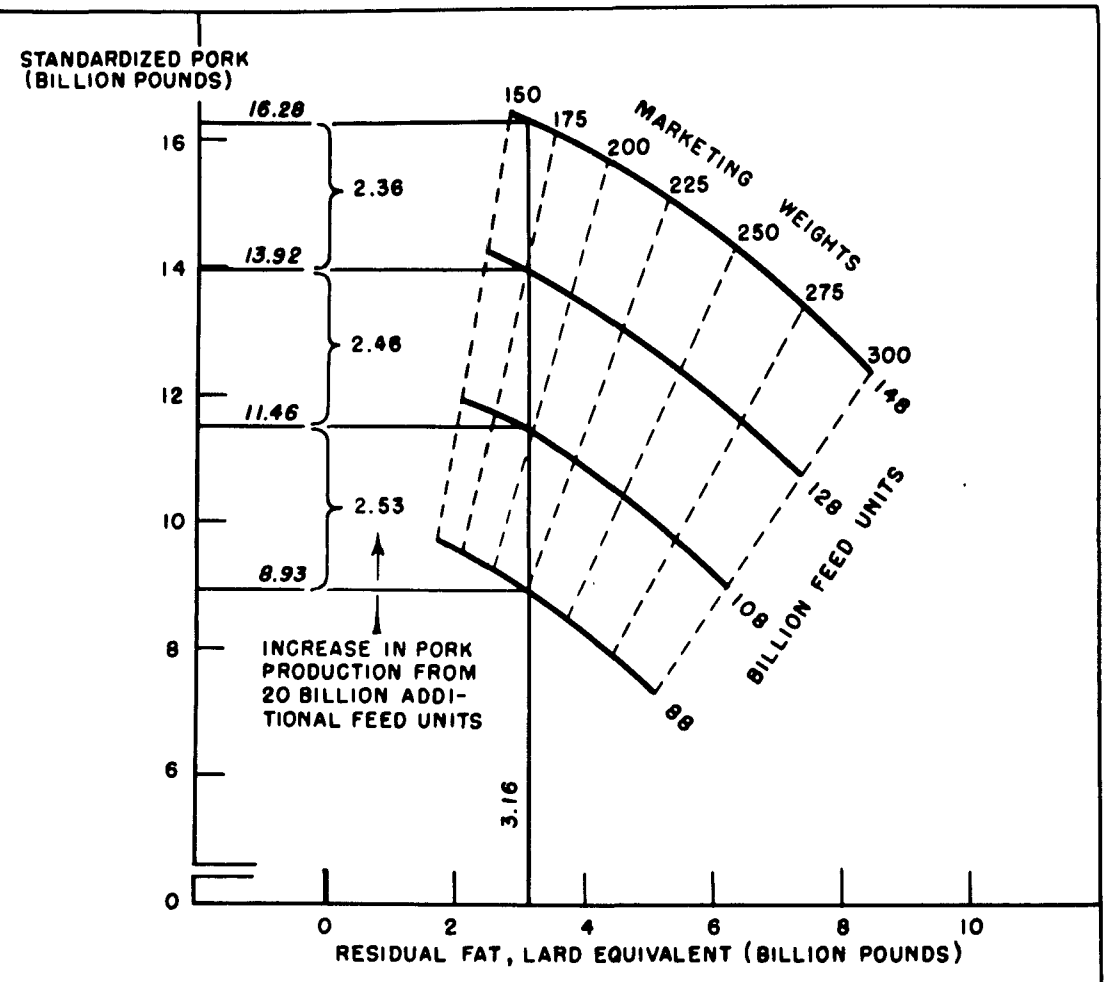

FIG. 15. MARGINAL FEED COST OF INCREASES IN TOTAL STANDARDIZED PORK PRODUCTION FOR THREE DECREASES IN MARKETING WEIGHT USING EQUAL CHANGES IN FEED CONSUMPTION.

As marketing weight is reduced the marginal feed cost of pork decreases. The reduction in marketing weight from 225 to 200 pounds increases pork production 2.53 billion pounds at a marginal feed cost of 7.91. For a 2nd reduction in marketing weight, 2.46 billion pounds of pork are produced and for a 3rd, 2.36 billion pounds, with marginal feed costs of 8.13 and 8.47 respectively.

Calculation of Marginal Feed Cost of Standardize

Item	Unit	150		175
		Pounds		Pounds
Number of hogs to produce				
8797.00 lbs. of standardized pork	Number	100.00000		88.80338
Residual fat lard equivalent	Pounds	1,546.510		1,943.609
Feed	Feed units	79,457.020		80,770.208
Increase in lard	Pounds		397.098	
Increase in feed	Feed units		1,313.188	
Marginal feed cost of lard equivalent (or edible fat)	do.		3.31	
Number of hogs to produce				
1546.51 lbs. of lard equivalent	Number	100.00000		70.65997
Pork	Pounds	8,797.000		6,999.685
Feed	Feed units	79,457.020		64,268.055
Decrease in pork	Pounds		1,797.315	
Decrease in feed	Feed units		15,188.965	1
Marginal feed cost of pork	do.		8.45	
Lard cost of pork			2.56	
Marginal feed cost of pork less feed cost of .42 lbs. fat	Feed units		7.06	
Marginal feed cost of protein (line above divided by .13)	do.		54.3	

[1] The calculations shown in the table are based on five or six decimal places. Calculati

Table 8

Cost of Standardized Pork and Residual Fat Lard Equivalent (Corn Belt Conditions, Including Breedin

	Data for Barrows and Gilts Weighing			
	175	200	225	250
	Pounds	Pounds	Pounds	Pounds
	88.80338	80.92744	75.38332	71.80227
	1,943.609	2,465.214	3,116.090	3,915.166
	80,770.208	83,170.279	86,681.651	91,392.436
098	521.605	650.876	797.076	976
188	2,400.071	3,511.372	4,710.785	6,151
51	4.60	5.39	5.91	6
	70.65997	50.76845	37.41261	28.29771
	6,999.686	5,518.648	4,365.936	3,476.655
	64,268.055	52,175.457	43,019.952	36,118.920
315	1,481.057	1,152.712	889.301	691
965	12,092,598	9,155.505	6,901.052	5,251
45	8.16	7.94	7.76	7
56	1.77	1.47	1.31	1
06	6.25	5.68	5.28	4
3	47.9	43.7	40.6	37

al places. Calculations using only the three decimal places shown will yield slightly different ans

nt (Corn Belt Conditions, Including Breeding Herd)[1]

ws and Gilts Weighing			
225	250	275	300
Pounds	Pounds	Pounds	Pounds
75.38332	71.60227	69.26226	68.20274
3,116.090	3,913.166	4,884.028	6,071.040
6,681.651	91,392.436	97,543.980	105,464.864
797.076	970.862	1,187.012	
4,710.785	6,151.544	7,920.884	
5.91	6.34	6.67	
37.41261	28.29771	21.95165	17.37366
4,365.956	3,476.635	2,785.539	2,240.908
3,019.952	36,118.920	30,886.957	26,865.646
889.301	691.096	544.631	
6,901.032	5,251.965	4,021.311	
7.76	7.57	7.38	
1.51	1.19	1.11	
5.28	4.91	4.58	
40.6	37.8	35.2	

ces shown will yield slightly different answers.

The calculations in the table follow the same principle employed in the charts above. The base for calculation is the standardized pork and lard from 100 hogs marketed at 150 pounds. In determining the cost of lard for shifts of 25 pounds in marketing weight, the number of hogs is adjusted to produce 8,797.0 pounds of standardized pork from hogs at each weight. Thus, at 175 pounds about 89 hogs would produce the same amount of pork as 100 hogs at 150 pounds, and at 200 pounds about 81 hogs would be needed.[1]

While the 89 hogs at 175 pounds produce the same amount of standardized pork as 100 hogs at 150 pounds, they yield 397.1 pounds more lard and require 1,313 more feed units. The marginal feed cost of the lard is 1,313 ÷ 397.1, or 3.31 feed units for the 150-175 pound range in marketing weight. This procedure is then repeated to determine marginal feed cost for lard at higher marketing weights. The trend in the cost of lard will be discussed later.

To obtain the marginal feed cost of pork, the lard production of 1,546.5 pounds from 100 hogs at 150 pounds marketing weight is taken as the base. About 70 hogs marketed at 175 pounds will produce the same total quantity of lard but will produce 1,797.3 pounds less standardized pork and require 15,189 less feed units. The marginal feed cost of pork for this reduction in pork is 15,189 divided by 1,797.3 or 8.45 feed units.

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[1]In case some concern in felt about how to produce 88.80338 hogs, as shown in the table, the answer is that for the Corn Belt as a whole this problem vanishes; e.g., the unit could be millions of hogs.

While the cost of lard was obtained by figuring the cost of an increment of lard, the cost of pork is figured by the reduction of pork by a small amount. In marginal analysis, the marginal or incremental unit of output is usually defined as a small increase or a small decrease; either one is satisfactory provided the unit is a small one. If there were any advantage in considering the cost of additional pork instead of the cost of a reduction in pork, this could be achieved by considering a reduction in marketing weight from 175 to 150 pounds.

As indicated in figures 14 and 15, the marginal cost of lard increases directly with marketing weight while the marginal cost of standardized pork varies inversely with weight. It does not follow, however, that if more pork is wanted, hogs should be fed to heavy weights and vice versa. If more standardized pork is desired rather than more lard, the change can be accomplished only by reducing weights and increasing the number of hogs marketed. Similarly, if lard is to be expanded relative to standardized pork, marketing weights must be increased.

Plausibility of Marginal Cost Results

Because heavy hogs have a higher proportion of fat and light hogs have a higher portion of lean, it is superficially plausible that the feed cost of lard is less for heavy hogs than for light ones and that pork is cheaper from light hogs. If the joint cost of pork is ignored when calculating lard cost, then lard is cheaper from heavy hogs. An

additional 100 feed units will produce more lard from heavy hogs than from light ones (figure 11), but the problem is, if allowance is made for the increase in pork in addition to the lard, will lard be cheaper from heavy or from light hogs? Common sense does not provide an immediate answer to this question. This is the sort of question, however, that has received elaborate attention from economists treating marginal cost in its general aspect. It is important to see if the above results are consistent with what would be expected on the basis of general economic principles.

For an industry under simple or atomistic competition to be in equilibrium, increased output must be secured at rising marginal cost and decreases in output at falling marginal cost. If a firm can increase output at falling marginal cost, then it is profitable to expand. If marginal cost continues to fall, continued expansion in size of firms will occur and atomistic competition will give way to monopoly. Thus the axiom, decreasing costs and competition are incompatible.

A similar situation exists with respect to "joint" products.[1] If two products are produced "jointly" but not in fixed proportions so that the production of one can be expanded at the expense of the other, the marginal cost of the expanded product must rise and the marginal cost of the contracted product must fall. Any other condition is not a stable

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[1] Joint products with variable proportions are more accurately termed "common" products, but this designation is less familiar.

equilibrium situation.[1]

Applying these principles to pork and lard production, if more pork is to be secured, the most efficient way is to reduce marketing weights and increase farrowings. The additional pork will be secured at rising marginal cost, as shown in the figure above. If a reduction in pork is wanted, the opposite adjustment will accomplish this at falling marginal cost. It can be shown that an increase in lard production will raise marginal cost and that a decrease will lower it.

For the next step, pork and lard are produced "jointly," but the proportions of each can be varied by changing marketing weights. To expand pork at the expense of lard, marketing weights must be reduced. This will increase the marginal cost of pork and decrease the marginal cost of lard (figures 14 and 15), which is the equilibrium condition.

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[1]The three other conditions may be disposed of as follows:

1. If the marginal cost of both the expanded and contracted product fell, then further expansion of the former and contraction of the latter would be profitable until ultimately only one of the products would be produced.

2. If the marginal cost of both the expanded and the contracted product rose, then a new equilibrium would be established by expanding the contracted product.

3. If the marginal cost of the expanded product fell and if the marginal cost of the contracted product rose, the proper adjustment would be an increase in the production of both products.

Consider the situation if the marginal cost of lard were reduced and if pork were increased with increase in marketing weight. An increase in the demand for lard would bring about an increase in marketing weight; if the marginal cost of lard were lowered, the result of the increase in demand for lard would be a reduction in marginal cost and hence in price of lard. Increases in demand do not ordinarily result in a decrease in price. The effect on pork would be equally strange. If the marginal cost of pork were raised by the increase in marketing weight, then the price of pork would be higher as a result of the increase in the demand for lard. Further increases in the demand for lard would lower the price of lard again and raise the price of pork--changes that seem unreasonable equilibrium adjustments to a rise in the demand for lard. Thus, from the consideration of general economic principles, the marginal feed cost of lard varying directly and of pork varying inversely with marketing weight seems logical.

The Effect of the Breeding Herd on Marginal Feed Costs of Standardized Pork and Residual Lard

The effect of the feed and gain of the breeding herd in influencing marginal cost is surprising. Superficially, this seems to belong in the category of an overhead cost, and it is a commonplace that such charges do not affect marginal costs. It is true that once pigs are weaned, except

for fattening the sow for market, the breeding herd costs are "fixed costs" that need not be considered in deciding on the weight to market the pigs (page 31 above). It is not true, however, that the breeding herd is constant if lard production is increased while pork production remains unchanged, for this involves a reduction in the number of pigs farrowed and thus a decrease in breeding herd costs. To secure any given change in pork (or in lard) the change in number of pigs and hence in breeding herd will be greater for light-weight hogs than for heavy hogs. Consequently, the influence of the breeding herd upon marginal feed costs will be greater for lighter hogs. The effect of this on the marginal cost of pork is quite different from the effect on the marginal cost of lard. When lard production is increased, the overhead charge is reduced by 11 percent for the lowest weight change and only two percent for the highest weight change (Table 8 above). The effect of the large reduction in the breeding herd at light weights is to increase the efficiency of lard production, thus lowering the marginal cost of lard for light weights more than in the upper range. In the case of pork, the large reduction in the breeding herd in the lower weight changes--e.g., 29 percent between 150 and 200 pounds marketing weight--coincides with a reduction in pork. Pork production is increased only if weights are lowered, in which case the breeding herd is increased; this increase in the breeding herd which is less efficient in the use of feed, increases the marginal cost of pork. Because the increase in the breeding herd is greater for any unit expansion in pork production at lower marketing weights than in the upper range, the

effect is to increase the marginal cost of pork more in the lower ranges.

The tendency to treat the breeding herd as an "overhead" or constant cost that has no effect on the marginal cost of pork and lard is an egregious error, and only the more dangerous because it is superficially plausible. It lowers the cost of lard and raises the cost of pork, especially at the lower marketing weights. The differential effect of the breeding herd at the various weights is greater than the change in the efficiency of the butcher hog and is largely responsible for the rise in the marginal cost of lard and the fall in the marginal cost of pork with increase in marketing weight. That this is true is shown from the analysis below of the butcher hog, excluding or only partially including the breeding herd.

The simplest method (Method I in Table 9), of excluding the breeding herd is to omit all the feed and the gain of the breeding herd. This leaves only the feed fed to the butcher hog after weaning and the total weight of the butcher hog marketed. Note that this method of calculation makes no allowance for the feed needed to raise a pig to 35 pounds. Thus, this type of after-weaning calculation includes the gain of the weanling pig but none of the feed needed to raise the pig. This is an error which is obvious when attention is called to it; it will be corrected below, but the results when compared with succeeding calculations furnish some clues to an understanding of marginal costs.

The marginal costs figured in this way are in two respects sharply different from the previous ones which included the breeding herd feed and

Table 9

The Effect on the Marginal Feed Costs of Pork and Lard of Omitting or Partially Including the Breeding Herd (Corn Belt Conditions)

Item	Unit	Marketing Weight of Butcher Hog					
		150-175	175-200	200-225	225-250	250-275	275-300
		Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Method I (excluding all feed and gain of sow)							
Marginal feed cost of lard	Feed units	8.07	7.30	6.96	6.79	6.78	6.84
Marginal feed cost of standardized pork	Feed units	5.69	5.76	5.82	5.86	5.86	5.84
Lard cost of standardized pork	Ratio	.71	.79	.84	.86	.86	.85
Method II (feed and gain after weaning)							
Marginal feed cost of lard	Feed units	6.45	6.30	6.35	6.44	6.61	6.77
Marginal feed cost of standardized pork	Feed units	6.63	6.65	6.64	6.61	6.54	6.45
Lard cost of standardized pork	Ratio	1.03	1.06	1.05	1.03	.99	.95
Method III (feed and gain from farrowing)							
Marginal feed cost of lard	Feed units	6.07	6.08	6.21	6.36	6.56	6.75
Marginal feed cost of standardized pork	Feed units	6.85	6.85	6.83	6.79	6.73	6.64
Lard cost of standardized pork	Ratio	1.13	1.13	1.10	1.07	1.03	.98
Method IV (inclusion of all breeding herd feed and gain)							
Marginal feed cost of lard	Feed units	3.31	4.60	5.39	5.91	6.34	6.67
Marginal feed cost of standardized pork	Feed units	8.45	8.16	7.94	7.76	7.57	7.38
Lard cost of standardized pork	Ratio	2.56	1.77	1.47	1.31	1.19	1.00

gain (repeated in Table 9 as Method IV). The marginal cost is greater for lard than for pork within the whole range of marketing weights shown; the ratio of the marginal costs varies from .71 at the lower weights to .85 in the upper range. The second change is that the marginal cost of lard decreases with increase in marketing weight while the marginal cost of pork increases directly with marketing weight. Both lard and pork costs change in the opposite direction here from the way they did when the breeding herd was included. The results shownhere conform to the prevailing notion that a pound of lard requires more feed to produce than a pound of pork and to the almost equally well accepted notion that the marginal cost of lard varies inversely and the cost of pork directly with marketing weight. This calculation would have some value for farmers who bought feeder pigs, although they are usually purchased somewhat older.

The error in the above calculation of figuring gain from birth while ignoring the feed from birth to weaning may be corrected either by including the pigs' share of the feed consumed by the sow during this period or by subtracting the gain of the weanling pig from each of the marketing weights. The effect of either method of adjustment--both of which are only partial since they make no allowance for maintenance of the sow during the several months from conception to weaning of the pigs--is to lower the cost of lard and raise the cost of pork. If adjustment is made deducting the gain made by the weanling pig from the total weight of the butcher hog marketed (shown as Method II in Table 9), the feed cost of lard is

slightly lower than pork for weights less than 250 pounds, and slightly greater for heavier weights. If adjustment is made by including feed needed to grow a weanling pig (Method III), the marginal feed cost of lard is less than for pork up to 275 pounds marketing weight. Thus, the more fully the breeding herd costs are included, the lower the marginal feed costs of lard and the higher the feed cost of standardized pork. Ignoring the cost of producing weanling pigs, standardized pork is cheaper than lard, but partially including the overhead makes lard cheaper than pork in the more common marketing weights (below 250 pounds), while allowing for total feed required and marketable pork produced (Method IV) shows lard to be considerably cheaper than standardized pork for light and medium marketing weights and 20 percent cheaper in the 250-275-pound range.

The partial correction for the feed needed to grow a weanling pig (Method III) provides evidence on another point, the trend of marginal costs with changes in marketing weight. It will be remembered that when no allowance was made for the feed needed to grow the weanling pig (Method I), the marginal cost of lard declined with increase in marketing weight while the cost of pork increased. The partial correction makes the marginal cost of lard a direct function of marketing weight and the marginal cost of pork falls very slightly with increase in marketing weight. It can be shown that a more complete correction will accentuate this effect.

This rather lengthy exposition of partial corrections for feed prior to weaning has emphasized its importance in the determination of marginal costs. The inclusion of all the feed and all the gains of the

breeding herd accentuates the influences that have been described for the partial correction. The explanation of why lard cost is less than standardized pork and why it increases with marketing weight does not make these tentative conclusions any less important. A breeding herd is a necessary cost and one that it is an error to neglect. The general conclusions are not changed for either a one- or a two-litter-a-year system, although in each case the figures vary slightly from the Corn Belt average. The influence of the breeding herd is somewhat greater for the one- than for the two-litter system.

Meaning and Interpretation of the Marginal Costs

Basically the meaning of marginal cost is simple--the added cost of another unit of product, or the reduction in cost from producing one unit less of product. The farmer who figures whether the gilts that farrowed in the spring should be sold for the seasonally high prices in the summer or should be bred again for fall farrowing and who debates between planting corn or soybeans in a particular field is thinking in terms that are equivalent to marginal analysis, in so far as he is using "good business sense" or good management. The fact that he has not heard of marginal cost and marginal revenue is not very relevant in appraising his action. Despite the simple basic idea of marginal cost, the calculation was seen to be very involved. The extent of its application remains to be

demonstrated. The marginals were first figured by holding feed constant, then the marginal cost of pork was figured by holding lard constant. In both cases the number of hogs was varied. Will these marginals apply for one hog if the marketing weight is changed from 200 to 225 pounds? In this case, do the marginals show what change takes place with feed, pork and lard all varying? Also, are the marginals appropriate to calculate the effect of change in weights and numbers of hogs marketed for the United States as a whole whether due to usual market forces or to government supported price changes?

If the costs that have been calculated under restricted conditions apply to the situations mentioned, this suggests that they are "true marginal costs" in the general sense that economists use the term, applicable for any given marketing weight or for any projected shift in weight regardless of shifts in numbers and feed consumption.

The three examples below explore the answers to these questions:

First example. The change in the feed consumption of a single hog between the marketing weights 200 and 225 pounds is figured by using the marginal feed costs of the increase in pork and lard. The feed cost of the extra pork and lard should check with the feed needed to obtain a gain in marketing weight from 200 to 225 pounds.

The portion of Table 8 above that is needed for examples 1 and 2 is repeated in Table 10 together with some additional calculations. The two

Table 10

Selected Data from Table 8, Used in Examples 1 and 2

Item	Unit							
Live weight	Pound	175		200		225		250
Change in live weight	do.		25		25		25	
Feed	Feed units	909.5		1,027.7		1,149.9		1,276.4
Change in feed	do.		118.2		122.2		126.5	
Standardized pork	Pound	99.062		108.702		116.705		122.859
Change in pork	do.				8.002		6.155	
Residual lard	do.	21.887		30.462		41.238		54.651
Change in lard	do.				10.866		13.324	
Marginal cost of standardized pork				8.165 (8.054)		7.943		
Marginal cost of residual lard				4.601 (4.997)		5.393		5.911

principal calculations needed for the shift in marketing weight are as follows:[1]

Increase in pounds of pork X marginal feed cost per lb. =	Feed Units
8.002 X 7.943 =	63.56
Then similarly, for lard:	
10.866 X 5.393 =	58.60
Total feed units for pork and lard =	122.16

The feed required for the increase in pork and lard together is 122.16 feed units, which checks with 122.2 feed units required for the gain in weight, shown at the top of Table 10.

In this instance the marginal costs apply even though pork and lard both vary. Thus the use of the marginal cost of pork is not limited to the simultaneous shifts in numbers and in marketing weight that are necessary to calculate it in the first place. This can be verified for other shifts in marketing weights, utilizing the data in Table 8.

Second example. Using the marginal feed costs, the feed required for the pork and lard obtained from a 200-pound hog may be compared with the feed consumption shown at the top of the table. Beginning with pork, note that there is no marginal cost figured at 200 pounds, but this can be calculated by averaging the marginals for 175-200 and for 200-225, which

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[1]While the calculations are not accurate beyond the first decimal place, it is important to test the accuracy of the method in the example and to eliminate the errors in rounding. For this reason three decimal places are shown.

yields the figure shown in parentheses. The calculations then are:

Pork -- 108.702 X 8.054	=	875.49 Feed Units
Lard -- 30.462 X 4.997	=	152.22 Feed Units
Total feed units for pork and lard	=	1,027.71 Feed Units

The total feed cost of the pork and lard calculated from the marginals check with the feed required per pig marketed at 200 pounds, which is 1027.7 feed units. The same holds true for the other marketing weights. Thus the marginal costs are as valid for a given marketing weight as for a change in weight. Straight line interpolation of the two adjacent marginals for 25-pound intervals in marketing weight yields accurate answers for a given weight.

Third example. A change in marketing weights and in numbers for the United States as a whole. The 1943-44 goal for hogs announced late in 1943 asked that hogs be marketed 25 pounds lighter in 1943-44 than the previous year and that farrowings be reduced about 17 percent. The effects of such a change in hog production will be examined by the results obtained above.

In the marketing year October 1942-September 1943, the difference between the weight (1) of all hogs and (2) of barrows and gilts purchased at 7 markets was 20 pounds[1], which checks with the 20.3 pounds figured above as the normal Corn Belt differential[2]. The goal which suggests

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[1]Livestock, Meat, and Wool Statistics, F.D.A., U.S.D.A. Calculation based on monthly data.

[2]This estimate is adjusted for farm and local slaughter.

lowering all slaughter weights from 255 to 230 pounds will be assumed to mean that the weights of barrows and gilts will be lowered from 235 to 210 pounds which is not precisely the same, but is the nearest round figure.

A 17 percent reduction in farrowings would be accomplished by an increase in sows and boars marketed as the breeding herd is reduced; similarly a later increase in farrowings when hogs are again increased would at first reduce the slaughter of sows. This time lag in the slaughter of sows is not an unimportant influence on the meat supply during rapid changes in number of pigs farrowed. Thus the 17 percent reduction in farrowings will mean a smaller decrease in total slaughter during the year in which it is accomplished. Significant as this is for the meat supply it does not represent new "production" of pork from feed but rather a liquidation of pork already converted from feed but just not marketed ("stored" in the sow's body). Since the marketing of the larger number of sows at an early date rather than a later date affects the feed supply only indirectly, the effect of the liquidation of breeding herds on the meat supply will not be figured here.[1]

All the calculations are on a per-pig basis. The total effect on the feed supply can be readily calculated from currently published figures on hog numbers.

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[1]The information for figuring the changes is all included in the Appendix.

The effects of a reduction in farrowings of 17 percent are direct and straight forward--17 percent less feed consumption and pork and lard production. For hogs averaging 255 pounds, which is 235 pounds for barrows and gilts only, 1,200 feed units are required and the yield is 119 pounds standardized pork and 46 pounds residual fat.

The lowering of the average slaughter weight of all barrows and gilts from 235 to 210 pounds, which is approximately the same as changing all hogs slaughtered from 255 to 230 pounds will have the effects shown in Table 11. This reduction in live weight of 9.8 percent effects a decrease in feed consumption of 10.3 percent, while edible pork and lard fall 11.5 percent. Standardized pork is reduced only 6.1 percent as contrasted with 25.5 percent for residual fat. The pork reduction amounts to 7.3 pounds per hog while residual fat declines 11.8 pounds.

By the method used in Table 8 the marginal cost of standardized pork and residual fat was determined for the interval 235-210 pounds for butcher hogs (Table 11). That these marginal costs are correct can be demonstrated by multiplying the change in pork and in lard by their respective marginal costs to obtain total feed reduction.

7.284 pounds pork X 7.874 feed units = 57.35 feed units

11.842 pounds lard X 5.600 feed units = 66.32 feed units

Total reduction in feed units = 123.67 feed units

The reduction figured in this way is 123.67 feed units as compared with 123.62, shown in Table 11. In example 2, it was found that

Table 11

Effect of Reducing Average Marketing Weight of all Hogs From 255 to 230 Pounds (Approx.)

				Reduction	
				Amounts	Percent
Live weight					
Including sow	Pounds	255	230	25	9.80
Barrows and gilts only	do.	235	210	25	10.64
Feed	Feed units	1199.73	1076.11	123.62	10.30
Dressed weight	Pounds	198.40	177.28	21.11	10.64
Edible pork and lard	do.	165.75	146.64	19.12	11.53
Standardized pork	do.	119.39	112.11	7.28	6.10
Residual lard	do.	46.36	34.53	11.84	25.54
Marginal feed cost of	Feed				
Standardized pork	units		7.87		
Residual lard	Feed units		5.60		

interpolation of the marginal costs shown in Table 8 yielded accurate values. In this example, the same is true: marginal costs do not have to be recalculated in the roundabout method of Table 11, but can be obtained by interpolation (as with logarithms, tables of square, etc.).

There remains to be considered the marginal cost ratios in reference to marginal values of standardized pork and residual lard. It has been shown that the marginal costs can be figured for any marketing weight or shift in weight. It can be shown that maximum production from given resources (feed) is achieved if the ratio of the marginal costs of two products produced together but not in fixed proportions is equal to the ratio of their marginal values. In such an example as the one here, since the government is suggesting the shift in marketing weights, the values should be marginal <u>social</u> values. Let's see what happened to the ratio of marginal costs.

At 255 pounds the ratio of the marginal costs was $\frac{\text{M.C.Pork}}{\text{M.C.Lard}} = 1.33$. At this weight then an additional pound of pork could be obtained at the expense of 1.33 pounds of lard. For the shift in weights from 255 to 230, the ratio increases to 1.42 as an average for this weight range. At 230 the ratio is 1.50. Thus, if a pounds of standardized pork is about as valuable as one and one-half pounds of residual lard, the marketing weight that will maximize production from a given feed supply is approximately 230 pounds for all hogs slaughtered or about 210 pounds for all barrows

and gilts. It can be shown that if standardized pork is more than one and one-half times as valuable as lard, a marketing weight of less than 230 pounds will produce a more valuable combination of pork and lard than 230 pounds or heavier from any given feed supply. Similarly, if pork is less than one and one-half times as valuable as lard, a marketing weight above 230 pounds will maximize production.

For such comparisons a few limitations of the above analysis should be remembered: (1) No difference in percentage waste by consumers is figured for hogs of various weights. (2) A pound of standardized pork averages about 10 percent more edible meat than a pound of pork purchased by the consumer. (3) All these results are tentative, awaiting additional information on hog composition especially. The appropriate sampling errors are not available.

Application of Marginal Cost Relationships

Knowledge of the output of pork and of lard at various marketing weights and the feed cost of shifts in the proportions of each produced make possible some refinements in crop yield comparisons. A good example is soybeans and corn. Both are grown on the same type of land, soybeans furnishing oil and meal used for feed, and corn providing feed which is in part used to obtain lard in addition to pork. As an illustration, the 1937-41 average yield of soybeans and of corn for the Corn Belt will be compared, using both the average and the marginal output relationships that have been developed.

The food production from each will be measured by assuming that the oil is first pressed from the soybeans and that the meal is fed in a balanced ration to hogs.[1] Similarly, the corn is fed to hogs.

Comparison based on hogs marketed at 225 pounds

Using 1937-41 average yields, an acre of soybeans in the Corn Belt will yield about 154 pounds refined oil and 870 pounds meal, which has a feeding value of 1,520 pounds of corn-equivalent in a balanced ration for hogs.[2] This feed will produce 154 pounds standardized pork and 55 pounds lard, or a total of 208 pounds of fat from one acre of soybeans. An acre of corn will produce 251 pounds standardized pork and 89 pounds lard. Thus soybeans yield more fat and less pork per acre than corn. If the pork and fat are added together, soybeans produce 363 pounds edible product and corn 340 pounds. The standardized pork includes only the edible portion, excluding skin and bone. Using dressed carcass weight, which is a closer approximation to pork as purchased in retail trade, soybeans produce 251 pounds of dressed carcass and, including the oil produced, a total product of 405 pounds as compared to 408 pounds from an acre of corn. These results are summarized in Table 12.

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[1] Thus this comparison does not involve the direct use of either soybeans or soya flour food.

[2] Using Jennings' conversion of 1.75 pound corn-equivalent for pound of soybean meal. U.S.D.A. Circ. 670.

Table 12

Comparison of Pork and Fat Production from an Acre of Soybeans and of Corn Using Corn Belt Yields 1937-41, Soybean Meal and Corn Each Fed in Balanced Ration

Product	Soybeans	Corn
Refined oil	153.85	
Standardized pork	154.30	250.92
Residual fat, lard basis	54.64	88.96
Lard plus oil	208.49	
Total edible product (Standardized pork plus lard and oil)	362.79	339.88
Dressed carcass weight	231.11	408.37
Total product (carcass plus oil)	404.96	408.37

Such comparisons have the merit of measuring the total food produced in terms of only two products--standardized pork and fat, or carcass weight and oil. If a value ratio can be determined for pork and lard, then the value of the product from corn and from soybeans can be determined. But this ratio is not easily determined, and it is subject to variation; a comparison in which no such ratio is needed would have a distinct advantage. The use of the marginal relationships makes possible such a comparison and indicates the change in marketing weights and in farrowings that will be needed. If more pork is desired instead of additional lard, reduction in marketing weights as shown in the next section will accomplish this. If more fat is wanted, however, the comparison shown in the second section below is appropriate.

Comparison based on lowering the weight at which hogs are marketed

If soybeans are regarded as a source of fat and corn as providing feed for pork production, among other uses, there is little basis for comparison of the two crops which compete for the limited acreage of Corn-Belt tillable soil. Soybean meal is an important protein feed in pork production, however, and the lard yield of hogs is an important part of the edible fat supply. Under some conditions it might be desirable to increase pork production at the expense of fat. If, e.g., a pound of standardized pork is twice as valuable as a pound of fat, both soybeans and corn will produce more food if they are used to increase pork production at the expense of fat. For soybeans this would mean that, first,

the oil would be extracted and then the meal fed to hogs; but the marketing weight of hogs would be reduced, which would increase pork and reduce fat production. The same amount of feed that is needed to market 83 hogs at 250 pounds will feed 36 hogs to 225 pounds. The fat production from the heavier hogs will exceed that from the lighter hogs by an amount approximately equal to the oil yield from an acre of soybeans. Thus, if additional soybeans are grown and in the same year farrowings are increased slightly and marketing weights reduced appropriately, total fat production can be maintained and the net effect of the soybeans is to increase pork production. Similarly, corn can be fed so as to increase pork, leaving lard production unaffected. When both are used solely to increase pork production, they can be compared directly. Using the 1937-41 average yields for the Corn Belt, in the marketing range between 225 and 250 pounds, soybeans will produce 313 pounds of standardized pork and corn will yield 319 pounds, or two percent more. This is based on a corn yield 2.25 times as many bushels as soybeans. Dividing 2.25 by 102 equals 2.20, the critical yield ratio. If corn yields 2.20 times as many bushels per acre as soybeans, the pork yield that can be obtained from each fed to hogs marketed in the 225 to 250 pound weight range is equal.[1]

If the net pork production from soybeans is compared with the fat and pork production from soybeans when the meal is fed to 225-pound hogs, the conditions under which the lowering of weights will produce more food can

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[1]This is based on the assumption of a protein supply not greatly different from that prevailing in recent years.

be seen. At 225 pounds marketing weight, the soybeans produced 154 pounds of standardized pork and 208 pounds fat as compared with 313 pounds of pork for the reduction in weight. If standardized pork is 1.5 as valuable as fat, the reduction in weight of hogs to obtain a maximum of pork is slightly more productive. Thus, the conditions necessary to make the use of soybeans (meal) to get increased pork instead of lard are not unreasonable ones.

Comparison based on increasing the weight at which hogs are marketed

Soybeans and corn (via hogs) are both important sources of fat. If one pound of fat is as valuable as one pound of edible pork (standardized), the product from an acre of corn or soybeans will be greater if used to yield fat exclusively, with no change in pork yield. This can be accomplished by a slight reduction in farrowings and a small increase in the marketing weight of hogs.

Using 1937-41 average yields for the Corn Belt, an acre of soybeans will yield 411 pounds of fat (including oil) if fed to increase marketing weights of hogs in the 225-250-pound weight range while corn will yield 418 pounds or two percent more.

The ratio of the fat yields of soybeans and of corn is the same as the ratio of the pork yields shown above (p. 98). The critical ratio, then, that was developed for pork is also valid for fat, a fact which suggests that for combinations in which some fat and some standardized pork is desired, the ratio would be equally valid.

The critical ratio mentioned is an essential datum in determination of production programs involving corn and soybean acreage and marketing weights for hogs, but it is not immediately applicable for four reasons, which will be discussed in turn.

1. The ratio computed applies to the Corn Belt as a whole, but should be developed for small areas to assure homogeneity, and to determine the areas in which soybeans have the greatest advantage relative to corn. As a first step in applying the critical ratio to small areas, it was calculated for each of the five Corn Belt States based on 1937-41 yields. They ranged from a low of 2.24 for Illinois to 2.54 for Iowa. Smaller areas should be compared before definite conclusions can be drawn.

2. The ratio is based upon a specific range of marketing weights for butcher hogs, and will vary with changes in slaughter weights. Thus, for the 200 to 225-pound range, corn outyields soybeans either in standardized pork or in fat production by five percent as compared with two percent for 225-250 pounds marketing range. The critical yield ratio drops to 2.14 for the lower weights.

3. The yield ratios of corn and soybeans for the Corn Belt and for three (Illinois, Missouri, and Ohio) of the five Corn Belt States are all less than five percent above the critical ratio.

This difference is very small in view of the following limitations:

(1) The yield of soybeans and/or of corn may change due to new varieties, new cropping systems, etc.

(2) Oil yield per bushel of soybeans may change, either by new varieties or improved crushing.

(3) Pork and fat production per 100 feed units is subject to some error; they may change with improved feeding and breeding.

(4) Fat pork such as fat backs, clear plates, etc., is assumed to have its rendered fat value even though not rendered.

(5) No estimate is made of the waste of fat by consumers. Informal observation suggests that the loss is significant. Contrary to the usual notion, the percentage loss is probably little affected by changes in marketing weight.

(6) No estimate is made of the value of the inedible offal from hogs. In maximizing pork production the inedible product will be larger than the usual proportion of inedible to edible; in increasing fat production the inedible product will be smaller than usual.

These several limitations show that the critical ratio cannot be determined with precision and that it will vary with technological changes, but they should not obscure the fact that the best current estimate is the one given above.

4. The ratio takes into consideration only one factor of production--land. No allowance has been made for the difference in labor required or availability of agricultural implements needed in production. Processing and distribution are likewise not investigated. Agricultural policy should include these considerations.

SUMMARY AND CONCLUSIONS

As the live weight of hogs increases, larger quantities of feed are required per pound of gain, but for two reasons the increase in feed requirements is less important than is sometimes implied. First, if feed units are used instead of pounds of feed, the rations fed to light and to heavy hogs are more comparable both in nutritive value and in cost. The increase in feed requirements as hogs mature is only half as great in feed units as in pounds of feed. The second reason is that in planning for a year in the future the tentative most profitable marketing weight is influenced not only by the feed requirements of the butcher hog but also of the breeding herd.

Using the feed requirements per 100 pounds live weight for 225-pound hogs as an index of 100, the index for the feed required per 100 pounds gain for the change in weight from 200 to 225 pounds is 104 and for 225 to 250 pounds is 107. About 10 percent more feed is needed per hundredweight gain between 225 and 275 pounds than is required to produce a 225-pound hog.

For the short-time decision on the most profitable marketing weight the feed cost comparisons between lighter weights and heavier weights are not necessary. Comparisons should be made between the total costs of keeping the hog for a given period against the increase in

value of the hog, making allowance for the usual seasonal changes and for discounts or premiums on heavier weights. Price comparisons for different weight hogs must allow for growth. For example, pigs farrowed in April average 150 pounds in October, 200 pounds in November and 250 pounds in December. These prices, then, are the appropriate ones to use in determining whether hogs should be held to heavier weights.

In determining the total feed costs of producing hogs the feed and gain of the breeding herd must be included. The final figures show that 290 feed units are needed per butcher hog marketed to produce a weanling pig of 35 pounds that will reach marketing weight; a 20-pound live-weight gain for the breeding herd is included.

It is estimated that 468 feed units are required to produce 100 pounds of marketable pork. The largest live-weight pork output per hundred feed units is in the 150- to 200-pound marketing range but production decreases only two and one-half percent in efficiency from 175 to 275 pounds. On the marginal basis, the decrease in the same range is 14 percent. The maximum output of dressed carcass per hundred feed units is obtained in the marketing range 225 to 275 pounds, about 75 pounds heavier than the output measured on a live-weight basis. Carcass produced per hundred feed units increases about one percent between 200 and 250 pounds marketing weight and decreases about one percent between 250 and 300 pounds. The decrease in the marginal output of carcass between 250 and 300 pounds amounts to 7 percent. The output of edible product (standardized pork plus lard) per hundred feed units increases throughout the range of data, although at a decreasing rate. This does not provide the answer

to the most efficient marketing weight, because of the changing composition of the carcass.

The most appropriate way to compare output for hogs of different marketing weights is to use a pork yield that has the same composition for hogs of various marketing weights. If heavy carcasses are trimmed more closely and light hogs less closely, pork yield of approximately standardized composition can be obtained in addition to the residual fat, lard equivalent. This standardized pork is used for all comparisons, but its validity as a measure of output is not limited to its practical use. For barrows and gilts marketed at 200 pounds, 78 percent of the total edible product is standardized pork (while the remainder is residual fat) but only half of the additional product is pork. At 250 pounds almost 70 percent of the total edible product is standardized pork but only one-fourth of the additional.

The possibility of obtaining pork and lard in various proportions makes possible the determination of the marginal feed costs of each. By varying the number of pigs farrowed and the marketing weights, pork production can be maintained while lard production and feed vary. The marginal cost of lard can then be obtained by dividing the change in feed units by the change in lard output. The marginal feed costs of pork can be obtained in an analogous manner. Using these methods the marginal feed cost of lard was found to be less than the marginal feed cost

of standardized pork for the usual range of marketing weights. The marginal feed cost of lard varies directly and the cost of pork varies inversely with marketing weight. The lower cost of lard than of pork is mainly due to the inclusion of the breeding herd. While the breeding herd is sometimes thought of as an overhead cost, it has an important influence upon the marginal feed cost of pork and of lard.

The marginal feed costs calculated under restricted conditions in which either the output of pork or of lard is held constant are applicable to wider situations. They can be used to determine (1) the change in feed consumption for a single hog between any two marketing weights, although both pork and lard vary simultaneously, (2) the feed needed to produce a hog of any given weight, and (3) the change in feed consumption accompanying simultaneous shifts in both numbers of hogs and marketing weights. The marginal costs determined for 25-pound intervals may be interpolated with reasonable accuracy.

In planning optimum pork and lard production from the standpoint of food needs, food production from limited feed will be maximized when the ratio of the marginal cost of pork and lard is equal to the ratio of their value; this is true for any value scale that is adopted.

The marginal cost relationship may be used to compare yields from alternate crops grown on the same land. As an illustration, the 1937-41 average yield of soybeans and of corn for the Corn Belt are compared.

Assuming that the oil from the soybeans is first extracted and that the meal is fed in a balanced ration to hogs, if hogs are marketed at 225 pounds, an acre of soybeans will produce 154 pounds refined oil, 154 pounds of standardized pork, and 56 pounds of residual fat, lard basis. An acre of corn will produce 250 pounds of standardized pork and 90 pounds of residual fat, lard basis.

By reducing marketing weight it is possible to utilize both the soybeans and corn to produce additional pork with no net change in lard and oil production. If this is done, corn will produce about two percent more pork than soybeans. If, instead of increasing pork production, it is decided to maximize the fat that can be obtained from an acre, corn will again produce two percent more fat than soybeans. In both cases production is equalized if corn yields 2.20 times as many bushels as soybeans. These figures are all based on the marketing range 225 to 250 pounds for barrows and gilts.

The yield ratios for corn and soybeans in the five Corn Belt States range from a low of 2.24 for Illinois to 2.54 for Iowa.

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A P P E N D I X

Table 1

Growth Curve for Hogs
Gompertz Curve Based on 800 Hogs in 12 Experiments

Age From Birth	Weight	
	Actual	Estimated[1]
Days	Pounds	Pounds
0	2.9	0
60.0	35.0	32.0
95.0	64.3	64.0
118.5	92.4	92.6
138.0	119.3	120.0
154.9	145.0	145.9
170.1	169.7	170.3
184.0	193.3	193.3
197.2	215.9	215.4
210.0	237.5	236.8
222.4	258.3	257.4
234.7	278.2	277.5
246.8	297.4	296.8
258.8	315.7	315.4
270.7	333.2	333.2
282.6	350.1	350.3
294.4	366.3	366.5
300.0		374.0
350.0		432.5
400.0		477.4
450.0		510.5
500.0		534.2
600.0		562.6
700.0		576.2
900.0		585.5

[1]Formula used: $W = 588(.009718)^{(.992275)^A}$ where W is estimated weight and A the age in days from birth.

Table 2

Feed and Gain After Weaning
Fitted Data for Each of the 12 Experiments per Pig Basis
Adjusted to Weaning Weight of 35 Pounds

Concentrates	Iowa Exp. 137B Live Weight	Iowa Exp. 288 Live Weight	Iowa Exp. 263 Live Weight	Iowa Exp. 309 Live Weight	Iowa Exp. 302 Live Weight	Iowa Exp. 137 Live Weight	Ohio Exp. 809 Live Weight	Ohio Exp. 820 Live Weight	Purdue Live Weight	Illinois Inter-mediate Live Weight	Illinois Rangy Live Weight	Missouri Bulletin No.73 Live Weight
Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
100	61.7	66.5	62.6	65.2	62.7	62.9	62.2	61.5	67.7	64.5	63.3	63.9
200	87.6	96.6	89.4	93.9	89.6	89.5	88.7	87.4	98.2	92.8	90.7	91.2
300	112.8	125.4	115.5	121.2	115.7	114.9	114.4	112.6	126.8	120.0	117.1	117.2
400	137.2	152.8	140.9	147.3	140.9	139.2	139.4	137.3	153.6	146.1	142.6	141.9
500	161.0	179.0	165.6	172.1	165.4	162.4	163.6	161.3	178.7	171.1	167.3	165.3
600	184.1	204.0	189.6	195.7	189.2	184.5	187.2	184.7	202.2	195.2	191.1	187.5
700	206.5	227.9	213.0	218.2	212.2	205.6	210.1	207.5	224.1	218.3	214.1	208.6
800	228.2	250.7	235.7	239.6	234.6	225.8	232.3	229.7	244.7	240.4	236.3	228.6
900	249.3	272.4	257.9	260.0	256.2	245.0	253.9	251.5	263.9	261.7	257.8	247.6
1000	269.9	293.2	279.4	279.4	277.2	263.4	274.9	272.6	281.9	282.1	278.5	265.7
1100	289.8	313.1	300.4	297.9	297.6	280.9	295.3	293.3	298.8	301.7	298.5	282.8
1200	309.1	332.0	320.8	315.5	317.3	297.7	315.1	313.4	314.6	320.5	317.9	299.0
1300	327.9	350.1	340.6	332.2	336.5	313.6	334.3	333.0	329.3	338.6	336.6	314.5
1400	346.2	367.4	359.9	348.2	355.0	328.9	353.0	352.2	343.1	356.0	354.6	329.1
1500	363.9	383.9	378.7	363.4	373.0	343.5	371.1	370.8	356.1	372.6	372.1	343.0
Standard Error of Estimate	13.1	24.4	15.6	8.4	25.9	24.5	7.9	6.7	13.9	6.7	3.2	9.6

Iowa data unpublished; Ohio data unpublished, experiments by W. L. Robison; Purdue data unpublished; Illinois data from the University of Illinois Agr. Expt. Sta. Bulletin No. 321, May 1929, by W.E. Carroll, et al; Missouri data from the University of Missouri Agr. Expt. Sta. Research Bulletin No. 73, January 1925, by A. G. Hogan, et al.

Table 3

Feed After Weaning and Live-Weight Relationship With Standard Error of Forecast for a Lot of 50 Hogs

Average of 12 Experiments Involving 800 Hogs Full Fed in Dry Lot

Feed	Live Weight	Standard Error of Forecast for a Lot of 50 Hogs
Pounds	Pounds	Pounds
0	35.0	0
100	64.3	6.8
200	92.4	12.0
300	119.3	16.9
400	145.0	21.5
500	169.7	25.7
600	193.3	29.7
700	215.9	33.3
800	237.5	36.8
900	258.3	40.0
1000	278.2	43.0
1100	297.4	45.8
1200	315.7	48.3
1300	333.2	50.7
1400	350.1	52.9
1500	366.3	55.0

Table 4a

Feed-Live-Weight Relationship for Hogs

Total Based on Pounds of Feed and Feed Units
And Incremental Based on Feed Units

Total Basis			Incremental Basis	
Live Weight	Feed After Weaning		Feed After Weaning	Gain in Live Weight per 100 Additional Feed Units
Pounds	Feed Units	Pounds	Feed Units	Pounds
35	0	0		
			32.3	23.2
50	64.7	50.7		
			118.8	23.1
75	172.8	137.5		
			227.3	22.9
100	281.8	227.8		
			337.0	22.7
125	392.1	321.7		
			448.4	22.2
150	504.5	419.6		
			562.1	21.7
175	619.5	521.7		
			678.6	21.2
200	737.7	628.5		
			798.8	20.5
225	859,8	740.6		
			923.1	19.8
250	986.3	858.1		
			1052.4	18.9
275	1118.3	982.0		
			1187.3	18.1
300	1256.3	1112.8		

Table 4b

Feed-Live-Weight Relationship for Hogs
Incremental Based on Pounds of Feed

Feed After Weaning	Incremental Basis Gain in Live Weight per 100 Additional Pounds of Feed
Pounds	Pounds
0	29.95
100	28.69
200	27.49
300	26.33
400	25.23
500	24.17
600	23.16
700	22.19
800	21.26
900	20.37
1000	19.51
1100	18.69
1200	17.90
1300	17.15
1400	16.43
1500	15.73

Table 5

Monthly Prices of Good and Choice Hogs, Chicago, Averages For Seven Marketing Years, 1934-41, Adjusted at Indicated Weights to Twelve Calendar-Year Averages, 1930-41 On Basis of Monthly Prices for 210-Pound Hogs[1]

Marketing Month	Prices per Hundredweight at Indicated Marketing Weights				
	150	200	250	300	340
October	$7.01	$7.62	$7.72	$7.56	$7.17
November	6.61	7.03	7.09	7.03	6.81
December	6.58	6.93	6.89	6.77	6.51
January	6.94	7.20	7.04	6.86	6.58
February	7.10	7.52	7.38	7.20	6.85
March	7.17	7.63	7.53	7.34	7.05
April	7.07	7.45	7.39	7.21	6.93
May	7.01	7.43	7.40	7.23	6.95
June	7.20	7.65	7.61	7.39	7.06
July	7.82	8.31	8.09	7.61	7.11
August	7.84	8.56	8.42	7.96	7.47
September	7.76	8.56	8.58	8.28	7.90

[1]The adjustment to 1930-41 prices is in order to remove secular trend from prices for 1934-41. Information on weight classes previous to 1934 not comparable with 1934-41 data.

Table 6

Average Chicago Prices for Years 1934-41 (Adjusted)[1] for Hogs Of Indicated Weights Arranged to Show the Differences In Prices When Marketed at Lower or Higher Weights

Month of Farrowing	Month of Marketing[2]	Prices at Indicated Weights				
		150	200	250	300	340
April	October	$ 7.01				
May	November	6.61	$ 7.03			
June	December	6.58	6.93	$ 6.89		
July	January	6.94	7.20	7.04	$ 6.86	
August	February	7.10	7.52	7.38	7.20	$ 6.85
September	March	7.17	7.63	7.53	7.34	7.05
October	April	7.07	7.45	7.39	7.21	6.93
November	May	7.01	7.43	7.40	7.23	6.95
December	June	7.20	7.65	7.61	7.39	7.06
January	July	7.82	8.31	8.09	7.61	7.11
February	August	7.84	8.56	8.42	7.96	7.47
March	September	7.76	8.56	8.58	8.28	7.90
(April)	(October)		7.62	7.72	7.56	7.17
(May)	(November)			7.09	7.03	6.81
(June)	(December)				6.77	6.51
(July)	(January)					6.58

[1]For explanation of adjustment see Table 5.

[2]Hogs farrowed in April under average Corn Belt conditions may be marketed at 150 pounds in October, 200 pounds in November, 250 pounds in December, 300 pounds in January, or 340 pounds in February. This is based on hogs that are finished on full feed but that are not full fed from weaning.

Table 7

Live Weight, Dressed Weight, and Pork and Lard Production Per 100 Feed Units at Indicated Marketing Weights--Corn Belt Conditions; Includes Breeding Herd

Item	Data for Barrows and Gilts Weighing						
	150	175	200	225	250	275	300
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Live weight							
Average	21.4	21.5	21.4	21.3	21.2	21.0	20.7
Additional[1]	21.7	21.2	20.5	19.8	18.9	18.1	
Dressed weight							
Average	16.1	16.3	16.4	16.5	16.5	16.5	16.4
Additional[1]	17.7	17.6	17.2	16.8	16.2	15.5	
Edible pork and lard							
Average	13.0	13.3	13.5	13.7	13.9	14.0	14.1
Additional[1]	15.2	15.4	15.4	15.4	15.2	14.8	

[1]The additional product represents the increase in product per 100 additional feed units for a change in marketing weight of 25 pounds; e.g., each 100 feed units fed to hogs between 150 and 175 pounds increases live weight 21.7 pounds.

Table 8

Output as Related to Input, per Hog Basis--Corn Belt Conditions; Includes Breeding Herd

Item	Unit	Data for Barrows and Gilts Weighing						
		150	175	200	225	250	275	300
Input:								
Feed	Feed unit	794.6	909.5	1027.7	1149.9	1276.4	1408.5	1546.3
Output:								
Live weight	Pounds	170.3	195.3	220.3	245.3	270.3	295.3	320.3
Dressed weight	do.	127.8	148.2	168.9	189.9	211.2	232.5	253.9
Edible portion	do.	107.7	126.1	145.3	165.4	186.1	207.6	229.7
Separable fat	do.	54.4	65.6	77.9	91.6	106.4	122.6	139.9
Separable lean	do.	53.3	60.5	67.4	73.8	79.7	85.0	89.8
Inedible portion:								
Skin and bone	do.	20.1	22.1	23.6	24.5	25.1	24.9	24.2

Table 9

Pork and Lard Yield from Three Ways of Cutting in Relation to Live Weight at Slaughter

Item	Unit	Slaughter Data						
Standardized cutting[1]								
Live weight								
Range	Pound	Less than 130		130-159	160-199	200-249	250 and over	
Average	Pound	106		146	183	218	289	
Pork yield in percent of live weight	Percent	60.4		62.2	61.4	60.8	60.3	
Cutting fat (lard equivalent) in percent of live weight	Percent	5.8		8.9	10.3	12.6	14.8	
Commercial practice[2]								
Live weight								
Range	Pound	180-220	220-240	240-270	270-300	300-360		
Average	Pound	200	230	255	285	330		
Pork yield in percent of live weight	Percent	54.9	57.9	59.5	60.9	61.8		
Lard yield in percent of live weight	Percent	15.1	13.6	12.7	12.1	11.7		
Standardized pork and residual fat[3]								
Live weight								
Average	Pound	150	175	200	225	250	275	300
Standardized pork yield in percent of live weight	Percent	58.6	56.6	54.4	51.9	49.1	46.2	43.0
Residual fat, (lard equivalent) percent of live weight	Percent	10.3	12.5	15.2	18.4	21.9	25.6	29.7

[1]Percentages computed from data in Food and Life, U.S.D.A. Yearbook, 1939. Original, Warner, K. F., et al, Cutting yields of hogs an index of fatness. Jour. Agr. Res. 48: 241-255, illus., 1934.

[2]Percentages computed from data in American Meat Institute Bul. HC-674, Mimeo., 1943.

[3]Based on Hankins and Hiner op. cit. Does not include breeding herd.

Table 10

Two Ways of Measuring Output per 100 Feed Units for the Usual Slaughter Weights

(Corn Belt Conditions, Includes Breeding Herd)

Item	Data for Barrows and Gilts Weighing						
	150	175	200	225	250	275	300
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
1. Physical composition basis:							
Separable fat	6.9	7.2	7.6	8.0	8.3	8.7	9.0
Separable lean	6.7	6.7	6.6	6.4	6.2	6.0	5.8
2. Standardized pork method:							
Standardized pork	11.1	10.9	10.6	10.1	9.6	9.0	8.3
Residual fat, lard equivalent	1.9	2.4	3.0	3.6	4.3	5.0	5.8

Table 11

Output of Standardized Pork and Residual Fat for Various Live Weights per 100 Feed Units. Corn Belt Conditions; Includes Breeding Herd

Item	Data for Barrows and Gilts Weighing						
	150	175	200	225	250	275	300
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Average:							
Standardized pork	11.1	10.9	10.6	10.1	9.6	9.0	8.3
Residual fat, lard equivalent	1.9	2.4	3.0	3.6	4.3	5.0	5.8
Total	13.0	13.3	13.6	13.7	13.9	14.0	14.1
Additional:[1]							
Standardized pork	9.6	8.2	6.5	4.9	3.1	1.4	
Residual fat, lard equivalent	5.6	7.3	8.9	10.5	12.0	13.4	
Total	15.2	15.5	15.4	15.4	15.1	14.8	

[1] The additional product represents the increase in product per 100 additional feed units for a change in marketing weight of 25 pounds.

Tables 12 and 13

Alternative Quantities of Standardized Pork and Residual Fat Obtained from the Number of Hogs of Various Marketing Weights That Can be Produced with 88 Billion Feed Units (1935-39 Average)

Live Weight of Barrows and Gilts	Feed Units	Number of Hogs	Pounds of Standardized Pork	Pounds of Residual Lard	For Each 25 lbs. Increase in Marketing Weight: Additional Lard Equivalent	Loss in Pork	Lard that Replaces One Pound of Pork
Pounds	Billions	Millions	Billions	Billions	Billion Pounds	Billion Pounds	Pounds
150	88.0	110.8	9.7	1.7			
					.40	.16	2.6
175	88.0	96.8	9.6	2.1			
					.49	.28	1.8
200	88.0	85.6	9.3	2.6			
					.55	.38	1.5
225	88.0	76.5	8.9	3.2			
					.61	.46	1.3
250	88.0	68.9	8.5	3.8			
					.64	.53	1.2
275	88.0	62.5	7.9	4.4			
					.66	.60	1.1
300	88.0	56.9	7.3	5.1			

Table 14

Alternative Outputs of Standardized Pork and Residual Fat
From Hogs at Seven Slaughter Weights for Four Quantities of Feed

Item	Feed	Data for Barrows and Gilts Weighing						
		150	175	200	225	250	275	300
	Billion Feed Units	Billion Pounds	Billion Pounds	Billion Pounds	Billion Pounds	Billion Pounds	Billion Pounds	Billion Pounds
Standardized pork	88	9.74	9.58	9.31	8.93	8.47	7.94	7.34
Residual fat	88	1.71	2.12	2.61	3.16	3.77	4.41	5.07
Standardized pork	92	10.19	10.02	9.73	9.34	8.86	8.30	7.67
Residual fat	92	1.79	2.21	2.73	3.31	3.94	4.61	5.30
Standardized pork	96	10.63	10.46	10.15	9.74	9.24	8.66	8.01
Residual fat	96	1.87	2.31	2.85	3.45	4.11	4.81	5.53
Standardized pork	100	11.07	10.89	10.58	10.15	9.63	9.02	8.34
Residual fat	100	1.97	2.41	2.96	3.59	4.28	5.01	5.78

Table 15

Alternative Outputs of Standardized Pork and Residual Fat From Hogs at Seven Slaughter Weights for Four Quantities of Feed

Item	Feed	Data for Barrows and Gilts Weighing						
		150	175	200	225	250	275	300
	Billion Feed Units	Billion Pounds	Billion Pounds	Billion Pounds	Billion Pounds	Billion Pounds	Billion Pounds	Billion Pounds
Standardized pork	88	9.74	9.58	9.31	8.93	8.47	7.94	7.34
Residual fat	88	1.71	2.12	2.61	3.16	3.77	4.41	5.07
Standardized pork	108	11.96	11.76	11.42	10.96	10.40	9.74	9.01
Residual fat	108	2.10	2.60	3.20	3.88	4.62	5.41	6.22
Standardized pork	128	14.17	13.94	13.54	12.99	12.32	11.54	10.68
Residual fat	128	2.49	3.08	3.79	4.60	5.48	6.41	7.37
Standardized pork	148	16.39	16.12	15.65	15.02	14.25	13.35	12.34
Residual fat	148	2.88	3.56	4.39	5.32	6.34	7.41	8.52