MEASURES OF PERFORMANCE IN SWINE

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Bachelor of Science

Southeastern State Teachers College

1932

Bachelor of Science

Oklahoma Agricultural and Mechanical College

1937

Submitted to the Department of Animal Husbandry

Oklahoma Agricultural and Mechanical College

in partial fulfillment of the requirements

for the degree of

Master of Science

1937

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ACKNOWLEDGMENT

The writer wishes to express sincere appreciation for the assistance and many valuable suggestions given him by Dr. O. S. Willham of the Animal Husbandry Department, Oklahoma Agricultural and Mechanical College in setting up, analyzing and conducting this study. His instruction and criticisms made this study possible.

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MEASURES OF PERFORMANCE IN SWINE

INTRODUCTION

The prime objective of swine breeders is to develop breeding stock that will farrow large litters of pigs which will produce a better quality of pork on a minimum amount of feed.

It has been demonstrated that efficiency of feed utilization in the animal kingdom is an inheritable characteristic and that it may be developed within a strain by breeding methods; however, its inheritance, as well as the inheritance of other factors which determine the quality of products produced, is extremely complex. For this reason it is difficult to establish reliable yardsticks for measuring production. Since there is considerable variation, as will be pointed out in this thesis, in the ability of swine to produce pork efficiently and in the quality of pork produced, it may be possible to develop a method of measuring this performance.

One important problem of the swine producer is to measure the growth of his animals and therefrom determine their relative efficiency in producing pork.

The purpose of this thesis is to determine some of the more reliable and more economical methods of measuring the efficiency of swine in producing pork.

REVIEW OF LITERATURE

Culbertson, et al, (1930, 1931, 1932, 1933, 1934)[1] have carried on an experiment with a record of performance for swine which was started when a group of men representing the Iowa swine interests met at the Iowa State Fair in 1923 to work out a plan. The Danish system of progeny testing swine was taken as the basis of the plan.

The purpose of the project was to determine definite standards for swine whereby the efficiency of breeding stock might be evaluated in terms of number of pigs per litter, rate of gain, economy of gains, and quality of carcass, and to work out a definite method of testing swine breeding stock on a large scale so as to make it possible to select high producing strains.

The method for determining these factors is to test representative pigs from nominated litters. The pigs were fed at the Iowa Experiment Station under practically identical conditions and slaughtered at the handy market weight of 225 pounds. Four pigs, two barrows and two

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C. C. Culbertson and others, Swine Performance Record; Litter Comparisons, Iowa Agri. Expt. Sta. Bull. No. 277, 1930.

C. C. Culbertson and others, Swine Performance Records; Litter Comparisons, Iowa Agri. Expt. Sta. Leaflets No. 28, 1932, and No. 29, 1933.

C. C. Culbertson and others, Swine Performance Record, Report on Agricultural Research, Agri. Expt. Sta., Ames, Iowa, 1931, pp. 26-27, and 1932, pp. 22-23.

C. C. Culbertson and others, Swine Performance Record, Report on Agricultural Research, 1933, pp. 31-32, and 1934, pp. 52-53.

sows, from nominated and accepted litters of Iowa herds were selected by the owners and sent to the animal husbandry section of the Iowa Experiment Station at weights averaging from 35 to 45 pounds when they were not over 63 days of age. Later this rule was changed to 35 to 50 pounds at 65 days of age. They were started on the feeding test at 65 days of age. Later this age was changed to 72 days, and the pigs were fed to a weight of 225 pounds. Only offspring of gilts or older sows that met certain requirements were accepted. To be eligible a gilt must have farrowed seven living pigs and an older sow eight living pigs. The sire and dam of each litter were required to be purebreds although not necessarily of the same breed.

Individual weights were taken. The initial weight was determined by the average of three wieghts taken on three consecutive days. The first of these three weights was taken when the pigs were 64 days of age. Weights were taken at the end of every 30-day period until the litter reached the final average weight of 225 pounds, determined by individual weights on three consecutive days. The average of the weights was considered as the final weight.

When the pigs reached the 225 pound weight, they were slaughtered and the carcasses graded or evaluated. The daily gains, the pounds of feed per 100 pounds of gain, and other valuable facts were determined about each pig. These results were used in rating the sires and dams of the respective pigs although no index number of one figure was calculated for them.

All litters differed rather widely in the gaining ability of the pigs, the feed requirements per unit of gain, and in the proportion and quality of the carcass.

Table 1 shows the number of litters, number of pigs, and the variability of the pigs used in this experiment in daily gains, pounds of feed per 100 pounds of gain, and in carcass score.

Table 1.

Year	Number of litters	Number of pigs	Age at beginning of feeding period	Range in daily gains	Range in pounds feed per 100 pounds gain	Range in carcass score	Range in value of carcass per 100 pounds of liveweight
1927 to 1929	44	176	65	1.1 to 1.7	358 to 468		$10.72 to $12.46
1931	20	80	65	1.0 to 1.5	346 to 451		10.02 to 10.50
1932	17	68	65	1.1 to 1.6	344 to 413		8.65 to 9.31
1933	21	84	72	1.0 to 1.6	344 5o 478	80 to 94	
1934	19	76	72	1.1 to 1.9	346 to 394	85 to 94	

From this table it will be seen that there was considerable variability in the ability of these pigs to make daily gains, in the pounds of feed consumed per 100 pounds of gain, and in the grade or value of the carcass.

The 44 litters tested in 1927 to 1929 made an average daily gain of 1.381 pounds. The pigs in 18 of the 44 litters or approximately 41 percent made less than average daily gains. The average amount of feed consumed per 100 pounds of gain was 393 pounds. The pigs in 18 of the litters required more feed than the average of all litters. Thirteen of the 18 litters that required more feed than the average were those in which the pigs gained less pounds daily than the average of the 44 litters. This indicates that daily gains and efficiency of feed utilization may be highly correlated.

Lush[2] studied the Danish system of progeny-testing swine and reported his findings in 1936. There are three phases to the system, which may be classified as follows:

(1) Cooperative Bacon Factories. The farmers sell their swine cooperatively through these factories. Between 80 and 90 percent of the swine killed for export now are killed in these cooperative factories. Their policy is to pay for each individual pig a higher or lower price according to whether it conforms well or poorly to the demands of the market.

(2) State Approved Swine Breeding Centers. The breeding centers, which are individual farms, are privately owned and operated but are under a certain amount of supervision by a district committee representing the farmers' organizations and the cooperative bacon factories. This committee visits each breeding center at least twice a year, scores the sows and boars intended for breeding, inspects the identifying marks of the individual animals, sees that pedigree records and sales records are individually kept, advises the owner about his breeding policy, and sees that the center is managed in an orderly and sanitary way. Each breeding center is also given a veterinary inspection each September and February and tuberculin tests of all animals over three months of age are made in April. The owner must discard all animals

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[2]J. L. Lush, Genetic Aspects of the Danish System of Progeny Testing Swine, Iowa Agr. Expt. Sta. Res. Bull. No. 204, 1936.

found unworthy either by the scoring committee or in the veterinary examination. Each center is obligated to send to the progeny testing stations each year enough test litters (of four pigs each) to average two pigs per scored sow in the herd. The scoring committee can specify certain sows from which test litters must be sent at the earliest possible opportunity. The government pays a small sum (about $20.00 per year in 1933-34) to each owner whose farm receives the designation of state approved swine breeding center.

(3) Progeny Testing Stations. There are five progeny testing stations which are largely financed by and partly supervised by the cooperative bacon factories but they are also supervised by the state agricultural experiment station.

From litters to be tested, four pigs are sent to the progeny testing station when about seven to eight weeks old and are fed there under standard procedure until each reaches a live weight of around 200 pounds when it is slaughtered at a nearby bacon factory and the meat is weighed, measured, and scored. The pigs are weighed individually every 14 days until they near the slaughter weight, when they are weighed every seven days.

As soon as the last pig of a litter has been slaughtered, the results are reported to the center owner and to the animal husbandry konsulent in the district where that center is located. A printed list showing the results for all litters which finished the test in the preceding three months is sent quarterly to all owners of breeding centers and to all animal husbandry konsulents. Soon after the close of the testing year (August 31) all information about litters which have completed the test during that year is assembled in a single report.

The data published in these reports are given much weight in selecting breeding stock both by general farmers and by the owners of breeding centers.

Naturally the figures for as many as three or four litters all sired by the same boar cannot often be available before the boar is 18 to 20 months old, and he will have been used rather extensively by that time. Hence it seems a reasonable conjecture that these figures are used most in determining whether or not the untested sons of a tested boar shall themselves be used and tested, but other reasons will largely decide which particular sons of the tested boars shall be tested.

Since the progeny testing started in 1907, there had been, by 1935, 10,893 litters tested, 769 litters being tested during the testing year of 1934-35. The following changes have occurred in the swine population during the 28 years over which Lush made this study:

The average daily gains changed from 1.2 pounds during the period 1910-15 to 1.4 pounds in the later years from 1930 to 1935.

> The rate of gain at the testing stations for the last six years has been about 16 to 18 percent higher than it averaged before 1923.[3]

> A decrease of about 8 percent in the amount of feed required for a pound of gain occurred in the seven years between 1922 and 1929.[4]

The results that Lush found with respect to feed utilization are shown in the following table.

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[3]Ibid., p.135.

[4]Ibid., p. 139.

Table 1a.

Period used	Total feed units used per unit of gain
1911-14	3.75
1920-23	3.63
1928-33	3.36

During the period studied there has been a slight increase in the length of body and thickness of belly, and a slight decrease in thickness of back fat. Lush found that there had been considerable change in general appearance and body conformation in the breeds. Other changes were found. Some correlation coefficients which Lush worked out are given in the tables below:

Table 2. Correlation between Litter Mates

Characters	Correlation
Daily gains	.34
Body length	.33
Thickness of back fat	.20
Thickness of belly	.19
Percentage of export bacon	.16

Table 3. Correlation between Half-sib Litters

Characters	Correlation
Rate of gain	x24
Economy of gain	.29
Body length	.39
Thickness of back fat	.44
Thickness of belly	.40
Percentage of export bacon	.27

Table 4. Correlation between Maternal Half-sib Litters

Characters	Correlation
Rate of gain	.23
Economy of gain	.12
Body length	.41
Thickness of back fat	.34
Thickness of belly	.28
Percentage of export bacon	.21

Table 5. Correlation between Progeny Averages of Sire and Son

Characters	Correlation
Rate of gain	.06
Economy of gain	.06
Body length	.13
Thickness of back fat	.16
Thickness of belly	.32
Percentage of export bacon	.02

The following table shows values assembled from Tables 2, 3, and 4, above, for the portion of individual variance which can be ascribed to heredity.

Table 6

Rate of gain	24 percent
Economy of gain	
Body length	54 percent
Thickness of back fat	47 percent
Thickness of belly	46 percent
Percentage of export bacon	20 percent

Ferrin[5] (1932) states that the record of performance work with swine in the United States has dealt with only a small percentage of the hog population, as it has not been employed in testing grade stock.

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[5] E. F. Ferrin, Production Tests for the Selection of Breeding Hogs, Annual Report, Amer. Soc. Animal Production, 1932, pp. 134-137.

Presumably the variation in the performance of grade swine is at least as great as in the selected group which has been the subject of experiment. If a means can be provided which a farmer may use for selecting stock in his own herd it will extend the possibilities of improvement in economy of production to all pork raisers. Such a plan has been worked out and is recommended by the National Swine Record of Performance Committee.[6]

The plan is as follows: To select brood sows from litters of pigs of heaviest weight at 56 days of age. This rule will enable a breeder to cull his own herd and retain the most valuable sows.

The prolificy and suckling ability of the dam are highly reflected in the weaning weight of her pigs. Weights at weaning time measure the pork producing ability of sows just as accurately as weights of litters when marketed.[7]

Cooperators in this project are required to follow the swine sanitation plan and to earmark each litter during the first week of age, reporting date of farrowing, breeding, and number of live pigs of each sex. The owner of the farm follows his own choice so far as the feeding plans are concerned but he is urged to full feed the pigs upon legume pasture. The litters are to be weaned at an average age of 56 days but a variation of 10 days in the ages of several litters weaned at one time is allowed. A difference greater than 10 days makes it impossible to calculate the weights accurately to the 56 day basis. It is recommended that each pig be weighed separately at weaning time but litter weights will be accepted if the total number and sex of the pigs of each litter are reported.[8]

It is not desirable to insist upon a large number of details but supervision of weighing and encouragement of the cooperators is very necessary. The county agents can help do this. It would be valuable to have accurate litter weights at marketing time as a means of checking the reliability of the weaning weights. It would also be valuable to have slaughter tests of at least two pigs from each litter to be made when the pigs weighed from 200 to 225 pounds each. It is recommended that market weights be taken and that slaughter tests be made.

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[6]Ibid., p. 136.

[7]Ibid., p. 136.

[8]Ibid., p. 136.

The efficiency of breeding stock varies greatly, and a workable plan for selecting the superior animals and eliminating the inferior producers will be of real value to hog raisers.

Shearer and Culbertson[9] (1934) working with a cross-breeding experiment with swine including four lots of four pigs each, studied the three-way cross with Duroc Jerseys, Poland Chinas, and Yorkshires. All lots were fed alike and according to the methods being used for record-of-performance litters.[a] The results secured in this experiment are summarized in Table 6.

a.

Table 6.

	Lot 1	Lot 2	Lot 3	Lot 4
Number of pigs in lot	4	4	4	4
Days required to reach 225 lbs.	102	112	120	132
Average daily gains (pounds)	1.59	1.47	1.35	1.35
Feed per 100 lbs. gain (pounds	345.70	362.67	394.05	378.37

The range in days required for each lot to reach an average weight of 225 pounds was from 102 to 132. The range in average daily gains made by the four lots was from 1.31 to 1.59 pounds. The range in the average number of pounds of feed required by each lot to put on 100 pounds of gain was from 345.70 to 394.05.

[9]P. S. Shearer and C. C. Culbertson, Outbreeding vs Crossbreeding with Swine, Iowa Agr. Expt. Sta. Annual Report on Agricultural Research, 1934, p. 46.

BEEF CATTLE

Beef cattle are similar to hogs in that the quantity and quality of the products cannot easily be measured without slaughtering the animals. Several methods of measuring and evaluating performance in beef cattle have been proposed.

By some of these methods attempts are made to measure the quantity and quality of products while the animal is on foot, while by other methods production is measured and evaluated by slaughtering.

Following are several examples which will give some idea about what has been done along this line.

Winters and McMahon (1933) proposed a record of performance for beef cattle. To obtain data on which to base the record of performance, 32 steers were individually fed at the following time. Twelve were fed in 1931-32 for 224 days and 18 were fed in 1932-33 for 196 days. In evaluating the data the 1931-32 and 1932-33 steers were grouped together. This was possible for both groups were very similar in breeding type, weight, age, and market grade; however, the initial weight of the 1932-33 steers averaged 75 pounds higher than the average of the 1931-32 steers. Both groups of steers were fairly uniform and their rations were essentially the same.

The 1931-32 steers were weighed at the beginning and at the end of the feeding trial and in addition were weighed every month. The 1932-33 steers were weighed at the beginning and at the end of the feeding trial and every 28 days. The 28 day weight was an average of three weights taken on three consecutive days.

In the 1932-33 trial with the 18 steers three day weighings were made every 28 days to determine how long it was necessary to feed cattle to determine their relative efficiency. In general, the most efficient steers were at the top and the least efficient ones at the bottom at the end of the first 28-day feeding period. The spread was much greater than at the close of the experiment. The number of steers used in this experiment was too small to make a correlation worth while, but it is likely that the rate of gains at the end of the first 28-day period and at the end of the 196-day period on 100 individuals would show a rather high correlation coefficient. Marked fluctuations in efficiency and in gains occurred from month to month. In general, the entire group went down or up as a unit. For these reasons alone a short feeding period would not be satisfactory to determine the relative efficiency of an animal with one another when fed at different times as will be necessary if a record of performance for beef cattle is to be developed. It is likely that 112 days represent the minimum duration of a feeding trial to reveal individual efficiency in beef cattle.

Winters and McMahon calculated several correlation coefficients in connection with this experiment. Three of the highest and most important ones are as follows:

Between daily gains and net profit was plus	0.7289
Between carcass grade and net profit was plus	.8000
Between daily rate of gain and a factor for efficiency of feed utilization was plus	.7141

Since selling price and daily gains each gave a high correlation coefficient with net profit, these two numbers were converted into an efficiency index by dividing the group's mean daily gain by the mean selling price and multiplying the result by the individual's sale value. This reduces the selling price to the same level as the daily gains.

The formula is given below:

$\frac{Md}{Ms} \times S = S_1$ (Selling price reduced to the level of daily gains)[1]

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[1] Winters, Lawrence M. and McMahon, Harry, Efficiency Variations in Steers, Minnesota Technical Bulletin No. 94 (1933)

S_1 was calculated for each animal. The reduced selling price "S_1" multiplied by daily gains is taken as the new efficiency index. This new efficiency index is called V which was calculated for each animal.

The correlation coefficient between V and net profit was+0.9064. This is the highest simple correlation coefficient obtained in this study.

The following recommendations were made by Winters and McMahon for a record of performance for beef animals:[2]

1. Purebred beef calves of either sex are eligible, and bull calves may be castrated during the test period. Correcting factors will be used to bring the values of heifers, bulls, and steers to a comparable basis. These factors will be determined from the comparative results of the first 200 animals of each group, (heifers, bulls, and steers) put through the test.

2. The birth weight is to be based on the average of three weights taken on the day of birth and two days following.

3. The final weight will be the average of five consecutive weighings taken on the 364th, 365th, 366th, 367th, and 368th days after birth.

4. Daily gains will be computed from:

$$\frac{\text{average final weight - average birth weight}}{365}$$

5. It is recommended that each calf be given satisfactory feed and care during the test period. Nurse cows or extra pail milk feeding, however, are to be prohibited unless there is some legitimate reason why the calf's dam is unable to nurse her calf.

6. At the time of the final weighing a competent individual or committee will authorize the scoring of the calf according to beef and breed conformation.

7. The final value, V, of the individual will be arrived at by multiplying the daily rate of gain by the figure arrived at in the S. column for body score.

[2] Winters and McMahon, Ibid., pp. 24-26

Table 7

A table for converting body score to a comparable level with daily gains.

Grade	Score S	S_1	Grade	Score S	S_1
	100	2.6438		80	2.1150
	99	2.6173		79	2.0886
Fancy	98	2.5909	Good	78	2.0621
	97	2.5644		77	2.0357
	96	2.5381		76	2.0093
	95	2.5116		75	1.9828
	94	2.4851		74	1.9564
	93	2.4587		73	1.9299
	92	2.4323		72	1.9035
Choice	91	2.4058	Medium	71	1.8771
	90	2.3794		70	1.8506
	89	2.3529		69	1.8242
	88	2.3265		68	1.7978
	87	2.3001		67	1.7713
	86	2.2736		66	1.7449
	85	2.2472		65	1.7184
	84	2.2208		64	1.6920
Good	83	2.1943	Common	63	1.6656
	82	2.1679		62	1.6391
	81	2.1414		61	1.6127
				60	1.5863

The average daily gain for the 32 steers used in this study was 2.115 pounds. This is taken as the reduced mean for body conformation. The actual mean body score is placed at 80. The spread for body score is from 100 down to 60, and the reduced score S_1 is placed opposite the actual body score. The value, V, is obtained by multiplying S_1 x D, (daily gain.)

For example, if a calf's birth-weight is 73 pounds and the final weight 894.75 pounds, the total gain is 821,75 pounds and the daily gain is 2.25 pounds. The calf has been given a score rating of 84: referring to the table above we find that the S_1 value corresponding to 84 is 2.2208 The calf's V index becomes 2.2208 x 2.25 = 4.9968, approximately 5.

8. The score card rating, daily rate of gain, and the V index would be included with the usual information given regarding an animal in its official pedigree and in the herd books.

The following will illustrate how this would appear:
141893 cow--Maybloom 16th (S,84; D.G., 2.25; V,5)

Among the 32 steers there was a considerable amount of variation in the pounds of gain per 100 lbs. of total digestible nutrients consumed which ranged from 14.77 to 21.80 lbs. and in daily gains which ranged from 1.44 to 2.51 lbs.

Holbert (1932) working with Angus, Shorthorns, and Herefords, proposed a record of performance for beef cattle based on the rating of sires according to their ability to sire prize winners. He surveyed the leading state and national shows from 1920 to 1932 for Aberdeen Angus, 1918 to 1932, for Herefords, and 1919 to 1930, for Shorthorns. Any state fair having five or more entries in a majority of individual classes qualified. A total of 304 Hereford, 209 Shorthorn and 198 Angus shows met the requirements; they included over 40,000 prize winners sired by 4,500 different bulls.

The scoring system he used is as follows:[3]

> The sire of a prize winner was credited with 5 points for a first: 4 for a second: 3 for a third: 2 for a fourth: and 1 for a fifth. All fairs were put on the same basis with the exception of the International in the case of Angus and Shorthorns. The American Royal and International were on the same basis, in the case of Herefords. Due to the size of these shows 10 points were given for the first prize winner and so on down to the tenth prize winner which received a score of one.

The high ten sires of prize winners from each breed as given by Holbert are as follows:

Shorthorn[4]

Rank	Name	No. of entries	Total Score
1	Cudham Dreadnaught	319	1269
2	Ballylin Rodney	255	1033
3	Browndale Count	258	987

[3]Holbert, J. C., Show Ring Winnings as a Means of Evaluating Sires, Annual Report, The American Society of Animal Production, 1932, p. 52-53

[4]Ibid., pp. 53-54

Rank	Name		No. of Entries	Total Score
4	Rodney		198	876
5	Prentice		248	871
6	Revolution		173	711
7	Bapton Prince		122	561
8	Supreme Commander		101	546
9	Lespedeza Sultan		109	464
10	Collynie Clipper Crest		86	378
	ABERDEEN-ANGUS			
1	Earl Marshall	183780	327	1444
2	Blackcap Revolution	287269	292	1331
3	Blackcap Bandolier II	363329	280	930
4	Black Belmore	336163	221	872
5	Elcho of Harviestoun	313295	164	637
6	Eston of Elmhill	254249	170	599
7	Ames Plantation Beau	219787	113	508
8	Prizemere 32nd	369132	107	498
9	Iremere 6th	366905	131	418
10	Eileenmere 4th	251504	93	412
	HEREFORDS			
1	Prince Domino	499611	559	2170
2	Perfection Fairfax	179767	372	1414
3	Repeater	289598	290	1208
4	Bonnie Lad 20th	355369	286	1189
5	Prince Domino 2nd	1222880	261	1092
6	Hazford-Tone	1093542	251	982

Rank	Name		No. of entries	Total Score
7	Braemore	666666	245	979
8	Hartland Mischief	1314000	203	971
9	Beau Blanchard	362904	207	902
10	Bocaldo 6th	464826	166	781

A great deal of publicity has been given to prize winners in breed papers, at shows, and in class rooms, whereas, it might have been more logical to have given the credit to the sires of the prize winners because the performance of the progeny of a sire is more valuable than the sire's conformation or any other factor in determining his breeding value.

In this study the progeny of 1395 Shorthorn bulls won 1839 points, or expressed in percentage over 64 percent of the Shorthorn bulls had less than four percent of the total score. In the other extreme less than three percent of the bulls had practically 55 percent of the total score.

Eight percent of the Angus bulls had over 60 percent of the total score.

> Holbert proposes a system of scoring for beef cattle based on prize winners:[5] A large number of fairs should be included and the bulls rated annually and publicity given to the leading sires. Possibly it would be worthwhile to let each show be an individual unit and recognize the high scoring sire of that show as a Register of Merit Bull placed in Class A. The next step, is ranking sires for the year and letting the high scoring bull be a Register of Merit bull in the AA class and any bull that can rank high over a five year period would be considered a Register of Merit bull in the AAA class. The 3 AAA bulls for the past five years are:

[5] Holbert, Ibid., p. 55

Browndale Count for Shorthorns; Prince Domino for Herefords; and Blackcap Revolution for Angus.

Sheets (1932) proposed a plan for evaluating beef cattle for a register of merit as follows:

This plan is based upon efficiency of feed utilization and the carcass grade. During the feeding period individual feed records are kept and at the end of the feeding period the animals are slaughtered and the carcasses graded for quality.

The animal's efficiency is designated by the number of pounds of cold dressed carcass it has produced for each 100 pounds of total digestible nutrients consumed, including mother's milk, grain, and roughage. The quality score is arrived at by grading the carcass and judging the rib for tenderness, combining the two on the basis of 65 points for carcass score and 35 points for tenderness score.

> These two scores, the one for efficiency, the other for quality, are multiplied together to arrive at a single value for performance, multiplying also by a purely arbitrary factor (p) which we have set at .065 in order that our final score may fall somewhere between 60 and 100 which is the scale on which we are accustomed to judging.[6]

Sheets applied this formula to a number of calves in the record of performance work. Among the most interesting of the data obtained have been those of three purebred Shorthorn calves, two steers and a heifer out of half-sisters. One of the steers and heifer were sired by the same bull. Table 8 summarizes the performance of these three animals.

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6 Sheets, E., Evaluating Beef Cattle Performance for a Register of Merit, American Society of Animal Production, 1932, pp. 41-44

Table 8

	Efficiency score	Carcass Grade	Tenderness	Carcass Grade & Tenderness Combined	Efficiency of Performance Score
No. 57 (heifer)	14.5	79	6.2	83	78
No. 58 (steer)	14.3	83	6.0	86	80
No. 59 (steer)	16.3	75	5.8	80	85

Thus steer No. 59, though his carcass was nearly half a grade inferior to the heifer's and more than two-thirds of a grade inferior to the other steer's, rated considerably higher in efficiency of performance because of his pronounced ability to produce beef from feed.

It may be that he is giving too much relative weight to the factor of efficiency. It is found that this is the more difficult of the two factors to fix in our animals, and therefore shall not be giving it undue importance.

Wentworth (1932) stated that apparently the traits which give value to the meat animal are the most complex characteristics with which we must deal in livestock breeding. They are not dependent on individual single units of heredity but on aggregates of such factors, many of which may be transmitted independently. We are involved with the phenomena of quantitative inheritance. Geneticists agree that quantitative inheritance is just as strictly Mendelian as the inheritance of color, horns, and other relatively simple characters.[7]

The consumer is interested only in quality meat at relative low prices, while the producer is primarily interested in animals which shall

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[7] Wentworth, E. N., Livestock Records of Performance and Their Value to the Meat Industry, American Society of Animal Production, 1932, p. 48

be most efficient as transformers of feed stuff into market livestock. The consumer's interest, quality meat, is too far-fetched to be an incentive to the livestock breeder in getting him to select for that characteristic. The commercial breeder uses as breeding stock animals which some pure-bred breeder has produced. The pure-bred breeder in turn got his breeding stock from a type developed by another breeder, and thus the man who selects and molds the type is too far removed from the consumer to make it possible for the consumer's interest to be considered to a great extent.

The present methods of measuring performance of livestock, judging in the show ring and on the market, does not compare with the grade of the carcass after slaughtering. More direct and accurate standards of values for carcasses and cuts, for efficiency of feed transformation and for reproductive value must be worked out.

The past methods of improvement have depended on the selection of sires and dams unduly appreciated because of their standing in the prize ring or their approach to arbitrary breed standards, both of which are records of expression of individual opinion, rather than definite measures of meat values.

The system of judging or grading livestock in the European fairs are superior to ours. Over there, for an example, a sow in the prize ring is thrown into one of four grades on her conformation, on her pedigree, and on her performance or her ability to produce pigs which have met the export standards at the testing stations. This does not give a perfect parent offspring test from the viewpoint of the geneticist, but it certainly approaches the transmitting power of his breeding stock more closely than under our present method of breeding.

DAIRY CATTLE

In measuring performance of dairy cattle, a different problem from that found in swine or beef cattle is presented. In the first place, the products are tangible and can definitely be measured with the animal on foot. In the second place, the performance of the sire can only be measured by the performance of his offspring.

Several attempts to establish reliable methods of measuring and evaluating performance in dairy cattle have been made by various workers in this field. Several examples are given to show some of the work that has been done.

Warwick and Copeland (1934) proposed a progeny test for dairy sires as follows:

Six or seven daughters of a sire is not a sufficient number on which to base a progeny test. Warwick and Copeland drew conclusions from a theoretical case evolving five multiple factors, that if a bull is mated to dams heterozygous (good producing dams) for these five factors it will take 1024 offsprings to get all possible combinations (individuals, each having a different genotype of the five factors), whereas if the bull is mated to dams homogeneous (low producing dams) for recessive factors 32 offsprings will be required to secure all possible combinations (genotypes) of the five factors.

Based upon this theoretical example they suggest that 20 to 25 offsprings from low producing (boarder) cows be used as the basis for a progeny test of well bred bulls. All bulls tested by this plan would be considered excellent if their daughters included none below average and if their daughters average hovered close to the mid-point between their dams average production and the maximum of the breed.

Feasibility of Test

It should be possible to maintain a test herd at relatively low cost. Low producing, (boarder) cows from herds of the same breed might be used. As soon as the low producing capacity of a cow under good nutritive conditions has once been established, it will be unnecessary to go to further expense of detailed records of her production. Such cows may be run as "beef herd" mostly on pasture, with a minimum of expense. When a group of such tester cows are brought together, they may be pasture bred to the young bulls if conditions are favorable. When the calves are dropped, the bull calves may be disposed of either when dropped or as young veal at the earliest feasible age. The dams of these bull calves may then be dried up and re-bred. The heifer calves may be allowed to nurse their mothers while on pasture. When the heifers come into their first lactations they should be well fed and milked for the first lactation. The initial record will show rather definitely whether the heifer has the ability to respond. If she does not make a credible showing in this time, it may be considered that it will usually be impossible for her to make even a fair record in succeeding lactations. Individuals which respond fairly well should be profitable producers. The poorest producers may be either sold for beef after the first lactation or thrown into the group of "testers." By resorting to the above scheme of management, it should be possible to place the testing of bulls on a relative low cost basis. It was advocated that this test should be used only as a tool to be used by institutions and private breeders who may be in a position to make a real contribution to the dairy breed.[8]

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[8] Warwick, B. L. and Copeland, O. C., A Dairy Sire Progeny Test, Journal of Heredity, Vol. 25, May 1934, pp. 177-181

Rice (1934) states that since type and pedigree are inadequate for selection, attention has recently been focused on indices for dairy cattle based on the proved-sire idea. A proved bull is one with a certain number of daughters with production records out of dams with or without production records (according to the idea of various investigators.)

The amount and quality of milk which a cow gives does not indicate her exact genetic make-up; nevertheless, her production record is tangible evidence of a sort and can be dealt with directly. There is no such tangible evidence indicating a bull's production capacity since he yields no milk. The production capacity which he may transmit to his daughters is determined indirectly by considering the records of his daughters or the records of his daughters compared to that of their dams.

Various attempts have been made in the past decade to formulate a bull index which will represent the bull's transmitting ability for amount of milk and percent of fat. Two methods of indexing bulls which have been suggested are as follows:

Goodale (1927) made a study of the transmitting ability of 68 Jersey sires, in one group, having five or more daughter-dam pairs, and 58 sires in another group. From this study he made the supposition that milk production of the daughter is about seven-tenths of the distance above the level of the lower parent, while butter-fat percent is about four-tenths of the distance above the level of the lower parent. Dr. Goodale proposed the following bull index as given by Rice:

Mount Hope Index-Milk

> Compute the average mature equivalent of the milk production of all daughters of the bull; also the average mature equivalent of the milk production of the dams of these daughters and take the difference between these averages.

If the daughters' average exceeds the dams' average to get the bull's milk index number add three-sevenths (or .4286) of the difference to the daughters' average.

If the daughters' average is less than the dams' average, subtract seven-thirds or 2.333 of the difference from the daughters' average to get the bull's milk index figure.[9]

Mount Hope Index--Butter-Fat Percent

"The index for percentage of butter-fat is obtained by similar operations, but with different fractions.

If the daughters' butterfat average percentage exceeds the dams' butterfat average percentage, add three-halves (or 1.5) of the difference to the daughters' average to get the bull's butterfat index.

If the daughters' average is less than the dams' average, subtract two-thirds (or .667) of the difference from the daughters' average to get the bull's index."

Another bull index formula reported by Rice was proposed by Wright. It is based on intermediate or blending inheritance It takes into account the number of daughter-dam comparisons giving increased weight to them as the number of such comparisons increases. It gives added weight to the breed average while the number of daughter-dam comparisons is small.

The formula is given as reported by Rice:

$$S = \frac{2}{N + 2} A + \frac{N}{N + 2} \quad (2D - Dam)$$

Where N = the number of daughter-dam comparisons, A = the breed average in production, D = the daughters' average production, Dam = the dams' average production, and S = the bull's index.

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[9] Rice, V. A., Breeding and Improvement of Farm Animals, McGraw-Hill Book Co., (1934) 307-313

[10] Ibid.

Dahlberg (1934) states that records kept on 181 cows of the Geneva, New York, Experimental Station Jersey herd shows that no production improvement was made from the time the herd was established in 1900 through 1921. In 1906 to 1908, inclusive, the herd averages 340 pounds of butterfat per cow per lactation period while, in 1919 to 1921 inclusive, it averaged 344 pounds.

In 1921, a program was started of proving the sires and partially proving the dams.

Partially Proving the Dams

In partially proving the dams, individual production records were kept and compared with one another. If the production of a cow and her daughters was low and unusually variable compared to the production of the rest of the herd, the strain was eliminated from the herd. On the other hand, those strains whose production was uniformly high were retained in the herd.

Proving the Sires

The first method of proving sires used at this station was that of comparing the dam's records with that of her daughters. In 1921, the records of all daughters which had been used in the herd up to that time were compared with the records of their dams. Of all the bulls used in the herd, from 1900 to 1921, there were only two whose progeny showed increased production over their dams. Comparisons of this kind were made between the daughters of the two bulls, then in the herd, and their dams. The daughters of one bull were better milkers than their dams. The production of the daughters of the other bull was a little below that of their dams and extremely variable. The first bull was retained as a herd sire and the other was slaughtered.

After several years of selecting by daughter-dam comparisons, Dahlberg suggested the following index formula as a method of calculating an exact numerical value for the total weight of butter-fat which would indicate the breeding value of the sire.

$$\text{Inheritance of dam} = 500 + \frac{\text{Dam} - 500}{3}$$

$$\text{Sire index} = \text{Daughter} + (\text{daughter} - \text{inheritance of dam.})$$

This formula was worked out to apply particularly to this herd as the herd's average butter-fat production is around 500 pounds.

This sire index gave values for the experiment station herd which were in aggrement with changes in herd production, that is, the herd production was increased by the bulls with the best sire index and vice-versa.

POULTRY

With poultry all or practically all of the record of performance and progeny testing work has been in connection with egg production since this is more important, economically, than meat production.

As in dairy cattle the quality and quantity of products can be measured without slaughtering the individuals concerned. Since inheritance of egg production is very complex, it is difficult to establish reliable methods, which are economical, for measuring their transmitting ability.

Some of the work in this field is given below:

Jull (1933) carried on a progeny testing experiment with poultry at the United States Animal Husbandry Experimental farm, Beltsville, Maryland.

The results are based on the first year egg records of daughters during the laying years 1928-29, 1929-30, and 1930-31.

The breeding stock each year consisted of males from dams that laid 225 eggs or more each and females that laid 225 eggs or more each in their first year of laying. All of the daughters, with few exceptions, that each dam produced each year, were placed in the laying house. During the three years there were 896 daughters that completed the first year of 365 days laying record.

The environmental conditions under which the daughters were kept during the three years were as nearly identical as it was possible to maintain.

In one study 19 different sires were mated to 19 different groups of dams. There were 135 dams in all 19 groups and they produced 785 daughters. Six sires produced daughters whose average egg production was over 200 eggs. Four sires produced daughters whose average egg production was between 190 and 200 eggs. Three sire's daughters were between 180 and 190 eggs. Five sire's daughters were between 170 and 180 eggs, and one sire produced daughters whose average egg production was less than 170 eggs.

The average egg production of each of these 19 different groups of daughters ranged from 168 to 229 eggs per daughter which shows that there is much variability of production of the daughters of different sires.

Another study was made to determine the difference in the dam's egg production when mated to different sires. The results of mating three dams with different sires are given in table 9.

Table 9

Dam	Sire	Daughter's average Egg Production
Dam 1	Sire 1	159
	Sire 2	217
	Sire 3	228
Dam 2	Sire 4	212
	Sire 5	210
Dam 3	Sire 6	172
	Sire 7	212

The results of this experiment indicate that the kind of progeny produced determines the relative value of a given mating rather than the breeding potentiality of either a given sire or dam.

Other matings were made to study the production of full sisters when mated to the same sire. The results of five such matings are given in Table 10.

Table 10

Sire	Dam		Daughter's average egg production
	Dam 1		175
Sire 1		full sisters	
	Dam 2		214
	Dam 3		239
Sire 2	Dam 4	full sisters	235
	Dam 5		245

This study indicated that when full sisters are mated to the same sire diverse results are frequently produced.

Other conclusions drawn from this project are:

> "The dam's record of egg production could not be used as a criterion of the dam's breeding potentiality. The record of egg production of the sire's dam could not be used as a criterion of the sire's breeding potentiality. The average egg production of a group of full sisters could not be used as a criterion of the breeding potentiality of any of the full sisters. The significance of progeny testing in breeding for egg production is determined by the results secured from a given mating."[1]

The Bureau of Animal Industry, poultry section (1934) has developed a national poultry improvement plan based on a record of performance.

Each state supervises its own work in cooperation with the national plan. The work in Oklahoma is carried on by the Oklahoma R.O.P. Association which is supervised by the Extension Department of the Oklahoma Agricultural and Mechanical College.

A record of performance is secured by trapnesting the birds during the entire period of the official year. During the hatching season each egg is marked with the number of the hen that produced it. The flock owner keeps all records of trapnesting, breeding, pedigreeing, and disposal of stock.

1Jull, M. A., Progeny Testing in Breeding for Egg Production, Poultry Science 13, January 1934, 44-51

All flocks in the association are placed under unannounced inspections and other inspections are made at regular intervals. The inspector has sole charge of the trapnests and eggs during all inspections.

To be certified, the birds must lay 200 eggs or more during the trapnest year. The eggs must weigh two ounces or more.

The work has been carried on for three years in Oklahoma, and the results summarized in Table 11.

Table 11

	No. of birds entering test	No. Approved (Those laying 200 eggs or more)	Average egg production of those approved	Range of production (hen laying highest and lowest number of eggs.)
1934	____	311	224	200 to 290
1935	2660	376	225	200 to 291
1936	2345	209	225	200 to 343

The range of production, (number of eggs laid in one year) for all 896 birds completing the test in the three years is from 200 to 343 eggs. It will be noted that this is a highly selected group of birds since all the hens producing less than 200 eggs annually were eliminated from the test.

Knox (1932) proposed a plan for keeping a record of performance for poultry in which there would be two phases: First, a random sample of eggs from each owner's flock would be gathered and sent to a central breeding station for hatching, and regular inspections of each flock would be made; second, a flock of pullets would be raised at the central breeding station for experimental work. The inspector would be a public official and at all times the central breeding station would be under his official management and supervision.

The inspector would make two visits to the breeder's flock during the year. One visit would be in the fall to band the birds and the other one prior to or early in the breeding season to obtain the random sample of eggs. These eggs must be procured in a definite and uniform method for each flock entered. This would be accomplished by the inspector who, upon his arrival, would remove all eggs from the nests, following which the first 100 eggs laid would be collected without selection. This would constitute the random sample of eggs. They would be placed in a container, properly sealed and delivered to the central breeding station. There the eggs would be incubated, the chicks hatched and raised, and the pullets kept for 12 months for production records.

The following records, which are given as Knox gave them in Poultry Science, would be gathered at the central breeding station and summarized for each flock.

1. Size of the eggs of the sample selected
2. Average fertility
3. Average hatchability
4. Viability of the chicks up to 10 weeks of age
5. Rate of body growth up to 10 weeks of age
6. Rate of body growth for the pullets up to 20 weeks of age
7. Average number of days to sexual maturity
8. Body size of pullets raised
9. Incidence of broodiness
10. Mortality in the laying stock
11. Body weight at 8 months of age
12. Average egg production.

This plan constitutes a proper random sampling of the flock and therefore is a truer indication of the actual breeding worth of a breeder's flock than any method used at the present time. A buyer would be enabled to purchase eggs or chicks which could be expected to produce similar results to those indicated in the official record obtained at the central breeding station.

Miscellaneous

Morris, Palmer and Kennedy (1933) carried on a breeding and feeding experiment with rats to determine the variation in efficiency of food utilization. Animals which showed either a high or a low efficiency were selected from an F_2 population which descended from the same stock. Those with high efficiency were mated together in an attempt to produce offsprings of high efficiency and similarity; those with low efficiency were mated together in an attempt to produce offsprings of low efficiency.

In succeeding generations inbreeding and selection was practiced in the hope of developing strains that would breed true for the two general levels of efficiency.

By such procedure, they developed two lines of rats, one of which was about 40% less efficient in food utilization than the other. Their work shows clearly that efficiency of food utilization is an inherited characteristic, and that it is possible to develop superior strains with respect to economy of gains.

Kleiber (1936) studied various factors effecting efficiency of food utilization. His study is based on what he found in a review of literature, on his knowledge of digestion and metabolism, and on data obtained from feeding trials.

He states that genetics of food utilization is by no means simple, that it depends upon many factors which are inter-related.

From his study he comes to the following conclusions about the various factors which effect efficiency:

1. Appetite (relative food intake): There is a lot of variability in the ability of animals to take in food among different animals of the same group. Because of this variability relative food intake is an important factor in food utilization.

In determining relative food intake, body size must be taken into consideration. To use this in selecting animals the total efficiency is determined by the food intake per unit of 3/4 power of body weight. The body intake is determined by the total number of pounds of feed consumed, but for comparisons the ration must be standardized.

2. Power of digestion: The power or rate of digestion does not seem to be very different among different animals of the same group for the reason it is not very important.

3. The stimulus for growth: There seems to be some chemical substances found in various tissues of the body, the amount of which indicates the rate or amount of growth. It would certainly mean a step ahead for breeding good utilizers of food if a single determination of a chemical substance in the blood, or better still, in the urine of young animals could be found thus permitting the estimation of their stimulus for growth and with it their storage capacity.

This is probably one of the most powerful determinants for food utilization.

4. Body size: The idea is expressed that efficiency is essentially independent of body size.

5. Relative gain: Instead of comparing the absolute rate of gain in weight in selecting good food utilizers as did Winters and McMahon (1933) in connection with a steer feeding trial, one should compare the

relative rate of gain, namely, the rate of gain per unit of 3/4 power of body weight.

Eaton (1932) studied the relation to one another of various factors affecting growth in guinea pigs. Working with 946 offsprings of inbred and 113 offsprings of outbred families, he calculated the correlation coefficients between several factors, <u>principally</u> those between weights and gains.

One set of correlation coefficients which he calculated was that of the dam's ages and the following factors.

	Litter size	Gains to 33 days	33-day weight	353-day weight
Inbred	.19	.26	.24	.18
Outbred	.31	.29	.29	.40

Another set is that between the weights of dams and the following factors:

	Litter size	Gains to 33 days	33-day weight	353-day weight
Inbred	.26	.30	.35	.26
Outbred	.34	.31	.37	.35

The weight or age of dam at farrowing time has but very little effect on the four factors mentioned above; however, the correlations between the dam's weight and the four factors is higher than that between the dam's age and the four factors in both the inbred and control stock.

Another group of correlation coefficients which he calculated was that between weights of the offspring at different ages. These coefficients are given in tables 12 and 13 as published by Eaton.

Table 12

Correlations between weights of young at ages indicated for the inbred stock of guinea pigs.

Age in days	Age in days: 3	13	23	33	53	83	173	263	353	443	533	623
Birth	0.94	0.82	0.77	0.71	0.60	0.49	0.44	0.41	0.35			
3		.88	.82	.76	.64	.53	.43	.40	.35			
13			.94	.87	.76	.64	.54	.48	.41			
23				.95	.85	.71	.58	.50	.43			
33					.89	.76	.60	.50	.47	0.44	0.40	0.43
53						.90	.69	.55	.50	.47	.41	.37

Correlations between weights of young at ages indicated for the control stock of guinea pigs

Age in days	Age in days: 3	13	23	33	53	83	173	263	353	443	533	623
Birth	0.96	0.87	0.79	0.72	0.70	0.54	0.50	0.48	0.47			
3		.91	.83	.78	.67	.55	.51	.49	.52			
13			.93	.89	.77	.64	.56	.53	.53			
23				.94	.83	.70	.62	.55	.56			
33					.81	.73	.65	.66	.66	0.61	0.62	0.68
53						.76	.67	.63	.62	.57	.56	.58

The correlation coefficient between birth and 3 days of age is+0.94 and+0.96 for the inbred and control stock respectively. The correlation continues to decrease as the length of time from birth increases.

The correlation coefficients between birth weights and weaning (33 days of age) weights was+0.71 and+0.72 for the inbred and control stock respectively. Both of these coefficients are highly significant.

The group in which weights between birth and 33-days of age were not recorded weaning weights gave a correlation coefficient with the weights at 173 days of+0.61 in both groups and with the weights at the end of 353 days of+0.46 and+0.61 for the inbred and control stock respectively. These correlations with weaning weights are significant and weaning weight may be used as a fairly good criterion for determining later weights up to 353 days of age in guinea pigs.

In the United States Department of Agriculture Yearbook (1936) it is stated that animals are more complex organisms than plants; the rate of reproduction is much slower and the effects of environment are more difficult to separate from the effects of heredity.

In animals, it states:

> "A few characters have been pinned to definite factors but they are almost inclusively characters that have no practical significance from the standpoint of performance, coat color in horses and cattle, for example, and plummage color in poultry. Even though there is little experimental evidence connecting any definite genetic factors with productiveness fertility, rate and economy of gain, or physical vigor, it has been demonstrated that these characters are affected by inheritance and subject to manipulation by breeding methods."[2]

The statement was made that we do not have accurate standards for judging the quality of meats, though progress is being made in that direction. We cannot tell with any degree of accuracy whether an animal is an efficient producer of high quality meat except by the slow and expensive method of individual feeding tests. Otherwise, about all we can do is to make a rough guess based on conformation. Judging livestock by conformation is not very accurate. The degree of accuracy may be judged

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[2]United States Department of Agriculture, Yearbook, Livestock Breeding at the Crossroads, 1936, 840-844

by a single example in another field. Dr. Gowen of the Maine Agricultural Experiment Station found that a seven-day test was about twice as accurate an indication of a cow's productive capacity for the year as scoring by the most expert judges, drawing on the garnered wisdom of the ages to tell from the cow's hoofs what she will produce.

"It is obvious that the lack of practical yardsticks is a handicap in breeding.

The process of getting down to essentials can be only partial, however, until we develop better criteria for measuring and evaluating animals from the standpoint of efficiency of feed utilization and apply them on a much wider scale than at present.

Testing for advanced registry in the case of dairy cows is an example of the use of practical criteria in judging animals. Another example is the use of speed records in breeding horses. In both cases, the use of these practical yardsticks has apparently brought results."[3]

Wallace (1934) stated that: in livestock research record-of-performance studies with cattle and swine continued to demonstrate the wide variation which exists in breeding efficiency and production efficiency of animals of similar ancestry. For an example, there was a difference of nearly five months in the time it took beef steers of the same breed to reach finished weights of 900 pounds; also calves that were heaviest at birth made the most rapid growth, required less feed per 100 pounds of gain up to weaning age, and reached final slaughter weights in the shortest time. However, no relationship was found between the weights of the calves at birth and the carcass grade they attained.[4]

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3. Ibid.

4. Wallace, Henry A., Animal Industry Problems, Animal Report of the Secretary of Agriculture, 1934, 94-95

EXPERIMENTAL PROCEDURE

Data used in this study were secured from an experiment conducted by the Oklahoma Experiment Station to compare limited inbreeding and outbreeding as systems of matings for swine. This experiment was initiated in 1923. The two strains of Duroc Jersey hogs, one inbred and the other outbred, were started from the same foundation stock. The inbred strain was maintained by half-brother x half-sister matings, and the outbred strain was maintained by the use of a non-related boar each generation. The environmental factors were made the same for both strains in so far as this was possible. The pigs were weighed at birth. They had access to a creep during the suckling period. They were vaccinated for cholera at four weeks of age and the boars, not saved for breeders, were castr - ated at six weeks of age. The pigs were weighed and weaned at 60 days of age. From weaning to market weight (225 pounds) the pigs were fed free choice on yellow corn, wheat shorts, and tankage which were in three separate compartments of a self-feeder. The pigs had access to a mineral mixture at all times. Pasture was used when available and alfalfa meal was used at the rate of five pounds per 100 pounds of feed when pasture was not available. No record was made of the alfalfa meal used.

In order to compare the inbreeds and outbreeds as to the amount of feed they required to put on 100 pounds of gain, 25 representative inbred and 26 representative outbred pigs were fed individually for a period of 30 days. Twenty-eight of these were fed in 1934, seven in 1934-35, eight in 1935-36, and eight in 1936. An effort was made to select the representatives from each group so that they would compare as closely as possible in age, weight and condition. The pigs selected for the individual feeding tests varied from 36 to 147 pounds in weight according to the age at which they were selected. After the 30 day feeding test was completed the pigs were placed with their respective groups and fed out to market weight. They were fed the same rations as they were fed in the groups.

The data from these individual feeding tests were used to study the question of how much variation there is in the amount of feed required to put on 100 pounds gain and to discover some practical method of measuring efficiency of feed utilization in swine.

The daily rate of gain from birth to weaning and from birth to a weight of 225 pounds was calculated on 499 of the inbred and outbred pigs.

Digestion trials with 39 pigs from each group (inbred and outbred) were conducted to determine if differences in the ability of the pigs to digest the feed consumed might be one of the factors effecting economy of gain. The pigs were paired for each digestion trial.

Results

With the 51 inbred and outbred pigs the amount of feed required to put on 100 pounds of gain during the 30-day individual feeding period and the period from weaning to market was calculated as was the daily rate of gain during these two periods. Since these pigs were fed in groups during the period from weaning to market only a rough calculation of their feed consumption during these two periods could be made.

Table 1 gives the daily gains for the two periods and table 2 gives the amount of feed required for 100 pounds of gain for the two periods.

With this group of pigs the range in daily rate of gain during the period the range in amount of feed per 100 pounds of gain was from 219 to 616. The range in daily gains made during the 30-day individual feeding period was from 0.3 to 2.4 pounds. For the same period the range in amount of feed per 100 pounds of gain was from 245 to 1040 pounds.

TABLE I

Daily gains made by 51 pigs during a 30-day individual feeding period and the period from weaning to market.

INBREDS			OUTBREDS		
Pig No.	30-day period daily gains	Weaning to market daily gains	Pig No.	30-day period daily gains	Weaning to market daily gains
375	1.3	0.8	$369X_2$	1.4	1.2
376	1.6	1.1	364	2.4	1.3
372	1.5	1.0	$369X_1$	1.8	1.3
373	1.3	0.8	368	1.7	1.2
396	0.9	0.7	487	1.1	1.1
402	0.6	0.8	454	1.0	0.6
393	1.2	1.5	424	1.2	1.0
394	0.8	1.5	422	0.6	1.0
395	1.0	1.6	442	0.7	1.2
344	1.0	0.9	421	0.3	1.0
345	0.6	0.8	317	1.7	1.2
261	1.7	1.0	312	1.9	1.3
252	1.1	0.9	324	0.9	0.7
256	1.7	1.0	$329X_1$	1.4	0.9
333	1.3	1.0	119	1.4	1.0
253	1.7	1.0	329	1.4	1.0
251	1.9	0.9	294	1.4	1.0
861	1.4	0.9	323	1.2	1.0
905	1.4	1.0	898	1.2	1.0
904	1.3	1.0	896	1.2	1.0
876	1.5	1.1	$899X_1$	1.3	1.1
702	1.5	1.0	894	1.1	1.0
715	1.1	0.9	776	1.8	1.6
701	0.9	0.9	771	1.8	1.5
731	1.0	0.9	775	1.4	1.2
			777	1.5	1.6
	310			338	

TABLE II

Pounds of feed required to put on 100 pounds of gain for 51 pigs during a 30-day individual feeding period and the period from weaning to market.

INBREDS			OUTBREDS		
Pig No.	30-day period lb. of feed per 100# gain	Weaning to market lb. of feed per 100# gain	Pig. No.	30-day period lb. of feed per 100# gain	Weaning to market lb. of feed per 100# of gain
375	430.5	391.3	$369X_2$	533.3	422.3
376	426.6	254.9	364	408.2	278.9
372	454.3	218.6	$369X_1$	452.8	294.7
373	447.5	386.1	368	512.7	302.6
396	471.5	522.3	487	387.5	324.7
402	748.9	428.9	454	468.9	616.1
393	406.4	368.2	424	454.0	362.4
394	586.6	368.2	422	610.5	358.7
395	489.3	346.3	442	613.6	303.9
344	341.3	289.8	421	1040.0	370.0
345	532.2	308.6	317	296.0	277.0
261	351.3	263.8	312	330.0	283.0
252	373.1	322.6	324	368.5	435.7
256	243.1	319.5	$329X_1$	373.0	344.6
333	466.3	318.2	319	416.2	295.9
253	460.9	331.3	329	404.8	313.6
251	350.1	348.9	294	374.4	276.4
861	411.4	371.1	323	487.7	305.2
905	452.7	359.7	898	505.4	434.0
904	453.8	375.2	896	414.5	408.9
876	402.2	332.1	$899X_1$	456.2	375.6
702	381.7	295.5	894	497.6	415.6
715	381.1	549.2	776	400.0	310.3
701	374.4	327.9	771	282.9	317.1
731	448.3	334.5	775	388.2	383.3
			777	430.6	296.9

An analysis of variance showed that there were no significant differences between the two lots (inbred and outbred) in the amount of feed required to put on 100 pounds of gain. According to the analysis of variance, there would have to be a difference of 45 pounds in the average amount of feed consumed by each lot per 100 pounds of gain for the difference to be significant. In the case of the 51 pigs there was a difference of only 0.06 pounds between the inbred and outbred lots.

Correlation coefficients between the following factors were calculated for the 51 inbred and outbred and for the 499 inbred and outbred pigs. The correlation coefficients for the group of 51 pigs are given as follows:

1. Between the daily rate of gain during the 30-day individual feeding period and the period from weaning to market was plus 0.36

2. Between the amount of feed required for 100 pounds of gain during the 30-day feeding period and the period from weaning to market was plus 0.56

3. Between the daily rate of gain and the amount of feed per 100 pounds of gain during the 30-day feeding period was — 0.54

4. Between weaning weight and daily rate of gain during the period from weaning to market was plus 0.21

The correlation coefficients for the group of 499 pigs are given as follows:

1. Between the daily rate of gain during the period from birth to weaning and the period from birth to a 225 pound weight was plus 0.41

2. Between birth weight and the daily rate of gain during the period from birth to market was plus 0.23

Digestion trials: For the 78 inbred and outbred pigs the average digestive coefficients ranged as follows:

1. For protein it was from 60.44 to 82.77 percent

2. For ash it was from 5.97 to 66.33 percent

3. For fat it was from 26.94 to 79.66 percent

4. For fiber it was from 8.04 to 59.76 percent

For the group of 499 pigs the range in daily rate of gain during the period from birth to market was from 0.47 to 1.18 pounds and during the period from birth to weaning was from 0.17 to 0.86 pounds.

DISCUSSION

It is realized that the data used in this study could have been improved by having the 30-day individual feeding tests conducted with pigs all of the same age and weight and all fed during the same period of time. This was impossible however, since it did not fit in with the breeding program at the experiment station. Since the environmental factors were made as constant as possible for the groups of pigs fed from time to time it should minimize any discrepancies. Since data on individual feed consumption of pigs are scarce it seemed worthwhile to make an analysis of this data in the face of the above criticism.

It also appeared that the inbreds and outbreds could be treated as one group since an analysis of variance did not disclose any significant difference in the efficiency of feed utilization in the two groups.

There is a great amount of variability among swine in the rate of growth, in the efficiency of feed utilization and in the carcass grade.

With the group of 51 inbred and outbred pigs the range in daily rate of gain during the period from weaning to market was from 0.6 to 1.6 pounds and during the 30-day individual feeding period it was from 0.3 to 2.4 pounds. The range in daily rate of gain for the group of 499 pigs during the period from birth to market was from 0.47 to 1.18 pounds, and during the period from birth to weaning it was from 0.17 to 0.86 pounds. With 121 litters of pigs Culbertson et al (1930-31-32-33-34) obtained a range in daily rate of gain of from 1.0 to 1.9 pounds, while Shearer and Culbertson obtained a range of from 1.3 to 1.6 pounds.

With the group of 51 pigs used in this study the range in amount of feed per 100 pounds of gain was from 219 to 616 pounds during the period from weaning to market and from 243 to 1040 pounds during the 30-day individual feeding period. With the 121 litters Culbertson et al obtained a range of from 344 to 478 pounds of feed per 100 pounds of gain, and Shearer and Culbertson obtained a range of from 346 to 494 pounds of feed.

The carcasses of the pigs used in this experiment were not scored. Culbertson et al obtained a range in carcass score of from 80 to 94 points. The carcasses were scored on the basis of 100 for ideal.

There was a considerable range in the digestive coefficients of the group of 78 pigs used in this study which ranged as follows:

1. For protein it was from 60.44 to 82.77 percent
2. For ash it was from 5.97 to 66.33 percent
3. For fat it was from 26.94 to 79.66 percent
4. For fiber it was from 8.04 to 59.76 percent

Since there is a great amount of variation in the various factors in the swine population it should be possible to select individuals and through breeding methods develop strains which will breed true for the desirable quality. The Danish swine growers have made some progress toward selecting breeding animals which will breed true for efficiency of feed utilization. In his study of the Danish system of swine breeding Lush (1936) found that the amount of feed required for a pound of gain decreased about eight percent in the seven years from 1922 to 1929. Morris Palmer and Kenedy 1933 developed two strains of rats, one of which was about 40 percent less efficient in food utilization than the other.

One of the greatest problems of the swine grower at the present time is to find a practical method of measuring the efficiency of feed utilization which is reliable. The most reliable method of accomplishing this would be to keep individual feed records throughout the growing and fattening period, and in keeping individual pig weights, but this is obviously impractical. It might be that the daily rate of gain during a certain period could be used as a method of measuring efficiency of feed utilization. To obtain the daily rate of gain would be simple and relatively inexpensive. The animals would be weighed at the beginning and at the end of the period and from those weights the daily rate of gain would be calculated. The reliability of using daily rate of gain as a criteria for determining the efficiency of feed utilization may be judged from a few examples. The correlation coefficient, for the 51 pigs used in this study, between daily rate of gain and amount of feed per 100 pounds of gain was - 0.54. This is statistically significant but is not great enough to be highly dependable for prediction purposes. Culbertson et al (1930-31-32-33-34) found that pigs making the greatest daily gain consumed less feed per 100 pounds of gain; with steers Winters and McMahon (1933) found a correlation coefficient of plus 0.71 between daily rate of gain and a factor representing efficiency of feed utilization. This correlation is large enough to be highly significant. In studying various factors affecting feed utilization, Kleiber (1936) concluded that the rate of gain per unit of 3/4 power of body weight could be used as a factor in determining efficiency of feed utilization.

In evaluating a period over which daily rates of gain can be used in determining efficiency the following cases are discussed. The correlation coefficient between the daily rate of gain during the 30-day individual feeding period and the period from weaning to market was plus 0.36. This is large enough to be statistically significant but it is too small to be of much value for prediction purposes. It seems that the 30-day individual feeding period was not important in being a method of determining efficiency of feed utilization. The correlation coefficient calculated between daily rate of gain during the suckling period and the period from birth to market weight for the 499 pigs used in this study was plus 0.41. This is high enough to be important, and it is likely that the rate of gain during the suckling period may be used as a factor in selecting pigs for breeding purposes.

To use body weights at various ages did not prove to be a reliable factor in judging efficiency of feed utilization. With the group of 499 pigs a correlation between birth weight and the daily rate of gain throughout the growing and fattening period gave a coefficient of plus 0.23. This is high enough to be statistically significant, but is too small to be of any value in selecting of breeding animals. With the group of 51 pigs a correlation coefficient between weaning weight and the daily rate of gain during the period from weaning to market gave plus 0.21. This is not statistically significant.

Based on the results obtained from a study of this problem and from the review of literature, the following plan for selecting breeding animals is proposed:

Under this plan there would be a National Swine Progeny Testing Association which would formulate uniform rules for all states. The work in each state would be under the control and supervision of a state organization operating under the rules and regulations of the National Association.

The farm of each swine breeder accepted in the association would be designated as a "state approved swine breeding center." Each swine breeding center would be regularly inspected each year by an authorized association inspector and announced inspections would be made.

The main points in the plan are as follows:

1. Pigs would be weaned at 60 days of age.

2. From the first four litters of each sow to be tested two pigs (one boar and one sow) would be selected at random for a feeding test.

3. After the first four litters, two pigs per year (one sow and one boar) from each sow would be selected at random for a feeding trial. This would be required for three years after which it could be continued at the breeders' will.

4. The pigs would be fed on the breeding center by the owner. Pigs from all litters would be fed in a group. They would be fed a standard rations one as near as possible recommended by the progeny testing association, and would be fed until they reached a weight of around 225 pounds.

Other pigs could be fed with the test pigs so long as standard conditions set up by the association were complied with.

5. Two pastures for the pigs on the feeding test would be provided for by the owner. The size of each pasture would be a minimum of one-eighth acre per animal for each hog to be fed at one time. The owner would be encouraged to provide green pasture during the feeding period.

6. All pigs in each litter would be weighed at birth and at weaning time. They would be weighed 90 days after the mean of their weaning dates and every thirty days thereafter until the average weight of the group neared the 225 pound weight after which they would be weighed every 15 days. The final weight would be taken in the presence of the authorized livestock judge on the day he scored the animals.

7. When the group mean weight was in the range of from 210 to 220 pounds, the association would be notified after which the livestock judge would be sent at the earliest possible date to score the pigs.

8. Careful preparation would be made for the livestock judge to score the pigs as follows:

a. Each litter would be placed in a separate pen
b. All pigs (the two being fed, those saved for breeding purposes and those culled) of each litter on the farm at that time would be placed in the pen.

9. The judge would score each pig in the litter and from that score compute the litter average score. Only the litter average score would be recorded. The scoring would be on the basis of 100 for ideal.

10. Daily gains of each animal would be calculated from the two weights, the weaning weight and the weight taken on the day the pigs were scored by the livestock judge.

11. Since one number is better than two as a basis for judging the value of an animal, the average daily gains and the average carcass score of the two pigs would be converted into one index number as follows:

$$\text{Index No.} = \frac{75\ (\text{ave. daily gain}) + \text{ave. litter score}}{2}$$

The average daily gain during the period from weaning to a weight of 225 pounds of the 51 pigs fed in this experiment was 1.1 pounds; 75 multiplied by 1.1 gives 82.5. This puts the score for daily gains up in the range of the carcass score. This formula is simple and will place the index number around 100 for ideal.

12. After the second and each succeeding index number has been completed a grand index number can be computed from them as follows:

Note: Each index number computed from each litter of pigs tested will be called merely an index number. When all index numbers, which a sow has, are combined to obtain a score for her this score will be called a grand index. N = the number of index numbers which a sow has.

$$\text{Grand index} = \frac{\text{Sum of index Nos.}}{N} \text{ plus } \frac{N(\text{Sum of index Nos.})}{100\ (N)} - \text{the}$$

square root of the Standard Deviation of index Nos.

13. The owner would be required to cull and castrate one-eighth of all boar pigs raised to weaning age and would be required to cull and sell for commercial purposes one-eighth of all sow pigs raised to weaning age not including those selected for the feeding trial. He would be required to furnish an affidavit testifying that this has been done.

The pigs would be culled (1) for health and vigor, (2) for body conformation, quality, and general appearance, (3) on the basis of the daily gains made during the nursing period, and (4) on the basis of the sow's production record (index number). It might be that all or almost all pigs from same sows would be culled while all those out of some sows would be kept on the basis of the sow's production record.

This type of progeny testing would be for the purebred swine breeders who are in a position to contribute toward the improvement of the swine industry.

The smaller breeders including the commercial breeders could use these principles for selecting breeding animals in an unofficial way. Any breeder could install a pair of scales, weigh his pigs at birth, at weaning and again at or near the market weight. He could use the daily rate of gain made by the pigs during the nursing period and during the total growing and fattening period as criteria for culling sows. These would be valuable factors to supplement the method of culling on general appearance of sow and offspring, number of pigs farrowed, etc., which is the only method used by most swine breeders at the present time.

SUMMARY AND CONCLUSIONS

1. The data used in this study were secured from one phase of an experiment designed to compare limited inbreeding with outbreeding in swine.

2. In this project the pigs were weighed at birth, 60 days of age and every 30 days thereafter until they reached a market weight of 225 pounds.

3. The pigs were fed in groups and records of the feed consumed during the period from weaning to market were made.

4. A special study of a group of 51 pigs which were fed individually for a period of 30 days was made. This study was made in an attempt to discover a practical method of measuring individual variation in the amount of feed required for 100 pounds of gain.

5. The range in daily rate of gain for the group of 51 pigs was from 0.3 to 2.4 pounds during the 30 day individual feeding period and from 0.6 to 1.6 pounds during the period from weaning to market.

6. The range in the amount of feed required for 100 pounds of gain for the group of 51 pigs was from 243 to 1040 pounds during the 30 day individual feeding period and from 219 to 616 pounds during the period from weaning to market.

7. The correlation coefficient between the daily rate of gain during the 30 day individual feeding period and the period from weaning to market for the group of 51 pigs, was plus 0.36. This is statistically significant but is too small for prediction purposes.

8. The correlation coefficient between the amount of feed required for 100 pounds of gain during the 30 day individual feeding period and the period from weaning to market for the 51 pigs was plus 0.56. This coefficient is statistically significant and may be high enough for pre-

diction purposes.

9. The correlation coefficient between the daily rate of gain and the amount of feed for 100 pounds of gain during the 30 day individual feeding period was -0.54. This coefficient is statistically significant and is high enough to be of value for prediction purposes.

10. The correlation between weaning weight and daily rate of gain during the period from weaning to market was plus 0.21 for the group of 51 pigs. This coefficient is not large enough to be statistically significant.

11. The range in the average digestive coefficients obtained from digestive trials on a group of 78 pigs was as follows:

a. For protein it was from 60.44 to 82.77 percent

b. For ash it was from 5.97 to 66.33 percent

c. For fat it was from 26.94 to 79.66 percent

d. For fiber it was from 8.04 to 59.76 percent

12. The range in daily rate of gain for a group of 499 pigs was from 0.17 to 0.86 during the suckling period and from 0.47 to 1.18 during the period from birth to a weight of 225 pounds.

13. A correlation coefficient between daily rate of gain during the period from birth to weaning and the period from birth to a weight of 225 pounds was plus 0.41. This coefficient is statistically significant and high enough to be important for prediction purposes.

14. The results secured from the 30 day individual feeding period were not too reliable for the purpose of predicting efficiency of feed utilization over a growing and fattening period.

15. According to the present study it is likely that the daily rate of gain during a feeding period is the most reliable index, which is practical for efficiency of feed utilization.

16. The great variation among swine in their ability to utilize feed efficiently indicates that it may be possible to develop strains by selection and breeding methods which are highly efficient in feed utilization similarly to what has been done with rats.

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