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J. L. McBee Jr.

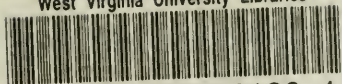
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Relationship of Dietary Protein Level To Carcass Characteristics and Growth Performance of Swine

WEST VIRGINIA UNIVERSITY
AGRICULTURAL EXPERIMENT STATION

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THE AUTHORS

J. L. McBee, Jr. and D. J. Horvath are Associate Animal Husbandmen; C. Lee and C. W. Scherer are Graduate Research Assistants.

WEST VIRGINIA UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE AND FORESTRY
A. H. VANLANDINGHAM, DIRECTOR
MORGANTOWN

Relationship of Dietary Protein Level To Carcass Characteristics and Growth Performance of Swine

J. L. McBEE, JR., D. J. HORVATH, C. LEE and C. W. SCHERER

SELECTION FOR MEAT TYPE may have altered the ability of swine to utilize protein, thereby necessitating re-examination of ration protein levels. Further, input:output values are needed for use in formulating swine rations.

In the study reported here, ration protein was chosen as the principal input, whereas output was lean cuts gained as estimated by the balance-by-slaughter technique. A secondary aim was to compare the classic nitrogen balance with other indices of efficiency of protein utilization.

In addition to examining feedlot performance and carcass characteristics, the effects of dietary protein levels on chemical composition and taste panel score of pork were compared in certain trials of this experiment.

Experimental Procedure

Five feeding and slaughter trials were conducted with a total of 108 pigs to determine the effect of dietary protein levels on gain in lean cuts. Treatments are shown in Table 1.

The same basic ration formulae (Table 2) were used in all five trials. Protein levels were changed by varying the amounts of No. 2 corn and 50 per cent dehulled solvent process soybean oil meal. For pigs of the same bodyweight the calculated calcium and phosphorus levels were equalized in trials 4 and 5 by adding dicalcium phosphate and sodium phosphate to the diets. An antibiotic supplement was included for these two trials.

Pigs were weighed, allotted to treatment randomly within sex, breed and litter, and placed in concrete-floored pens with self-feeders. Pigs were watered twice daily in concrete troughs for all trials except number 2, for which automatic waterers were used. In all trials except

TABLE 1
Experimental Treatments

Level	Period			
	I	II	III	
A. Crude protein levels fed (calculated), per cent				
High	21	18	15	
Medium	18	15	12	
Low	15	12	9	
B. Weight limits for respective periods, lb.				
Trial				
1	February-June, 1960	weaning - 100	100-150	150-200
2	May-September, 1960	weaning - 100	100-150	150-200
3	December, 1960-May, 1961	weaning - 75	75-125	125-200
4	November, 1964-March, 1965	weaning - 75	75-125	125-200
5	May-August, 1965	weaning - 75	75-125	125-200

TABLE 2
Ration Formula

Protein, per cent					
Calculated protein	21	18	15	12	9
Protein determined by Kjeldahl analysis of pooled samples	20.8	17.6	15.0	12.0	9.0
Ingredients					
Corn, ground	64.2	71.2	78.2	85.4	92.4
50% soybean oil meal	29.4	22.4	15.4	8.2	1.2
17% dehydrated alfalfa meal	3.0	3.0	3.0	3.0	3.0
Mineral premix ^a	2.0	2.0	2.0	2.0	2.0
Ground limestone	0.4	0.4	0.4	0.4	0.4
Vitamin premix ^b	1.0	1.0	1.0	1.0	1.0
Antibiotic supplement ^c					

^aThe mineral premix added 50 ppm Zn, 10 mg. Fe, 1 mg. Cu, and 10 mg. Mn per pound of ration. Zinc was raised to 75 ppm January, 1961, and to 100 ppm November, 1964.

^bThe vitamin premix added 90 I.U. vitamin D, 1 mg. carotene, 0.5 mg. riboflavin, 2 mg. calcium pantothenate, 2 mg. niacin and 5 mcg. B₁₂ per pound of ration.

^cAntibiotic supplement provided 20 gm. chlortetracycline per 908 kg. of diet in Trials 4 and 5 only.

number 3 the pigs were removed from feed for 24 hrs. at approximately 200 lb., then slaughtered, and dressed packer style. At the beginning of each trial representative pigs were slaughtered and carcass data were recorded.

The carcasses were chilled at 36° F for 48 hrs. The dressing percentage was obtained from the fasted weight and the weight of the chilled carcass. Backfat thickness was obtained from the average of measurements taken at three positions: the first thoracic, the last thoracic, and the last lumbar vertebra. Carcass length was measured from the anterior edge of the first rib near the vertebral column to the anterior edge of the aitch bone. The carcasses were then cut according to the procedure recommended by the Pork Committee at the Reciprocal Meats Conference (1952). The percentage of lean cuts was calculated from the total weight of four trimmed lean cuts (ham, picnic, Boston butt and loin) and the weight of the chilled carcass or the weight of the fasted animal before slaughtering. The value of gain in lean cuts was obtained from the difference in lean cuts of the experimental animals and that of the random pig from each litter slaughtered at the beginning of the experiment. In a similar manner, percentage of fat cuts was obtained from belly, jowl, leaf fat, backfat and fat trim. A tracing on acetate paper was made of the *longissimus dorsi* between the 12th and 13th ribs.

Trial 1

Pigs in trial 1 were twelve Durocs averaging 48 lb., sired by the same boar, and from related sows. Two barrows and two gilts from each of three litters were allotted to groups. The four pigs in each protein group were penned together. Two additional pigs were selected from two of the same litters without regard to sex, and slaughtered the day the experiment started.

Trial 2

The twelve pigs in trial 2 averaged 57 lb. and were from one litter of Yorkshires and one Duroc x Yorkshire litter. (The sire of the cross-bred pigs was not the same as in trial 1.)

Three barrows and three gilts were selected from each litter and randomly allotted within sex and litter to treatment. An additional pig from each litter was selected without regard to sex and slaughtered to estimate the initial composition. This study was conducted in the same manner as was trial 1 except that classical nitrogen balance was determined for the barrows for approximately 1 week on each protein level. Details of the method are presented by Scherer (1962). No effort was made to restrict intake of the barrows in the metabolism crates. However, when the barrows were removed from the crates after the second collection period they were much lighter than the gilts and therefore they were penned separately.

One barrow was sacrificed after the second collection period because of lameness. The amount of feed eaten by this barrow was estimated and subtracted from the total for his group. This barrow is excluded except for the second period of the nitrogen balance study.

Due to retarded growth and apparent alternations in the lean:fat ratio in the pigs confined in crates, no further balance studies were conducted.

Trial 3

The thirty-six pigs in trial 3 were from three litters of Duroc x (Yorkshire x Tamworth) and four litters of Durocs. The crossbred sows were littermates and the Duroc sows were littermates. (These Durocs were not related to those used in trial 1. All pigs were sired by the Duroc boar that sired the crossbred pigs in trial 2.)

Average initial weight of the Durocs was 36 lb. and of the crossbreds 51 lb. Strains and sexes were penned separately so that in this trial separate feed data could be obtained for each sex of each strain on each level of protein.

The first pig in each group to reach 75 lb. was slaughtered. Durocs slaughtered at this time were barrows and the crossbreds were gilts. Slaughtering the heaviest pig may have influenced the outcome. However, there is the advantage that the remaining pigs were within a narrow weight range.

At 125 lb., a barrow and a gilt from each strain and each protein level were slaughtered. The remaining pigs were fed to approximately 200 lb. then slaughtered.

Pigs in trial 3 were not shrunk before slaughter since full weight was used to estimate cutting yield of the pigs remaining on the experiment.

A section consisting of the 10th, 11th, and 12th ribs was cut from the left loin of each carcass and frozen. It was later partially thawed and the *longissimus dorsi* muscle separated from external fat and bone and then ground. Crude fat was determined directly as ether extract.

The data from trial 3 were subjected to analysis of variance by the method of fitting constants. Differences between means required for significance were calculated as described by Snedecor (1956).

Partial efficiency coefficients were calculated as:

$$\frac{\text{additional gain in lean cuts}}{\text{additional protein consumed}}$$

for the respective increments of protein between the low and medium and between the medium and high protein regimes.

Trials 4 and 5

All animals used in the fourth trial and one-third of those used in the fifth trial were purebred Durocs; the others in the fifth trial were Duroc x Yorkshire crossbreds. In each trial, three barrows and three gilts of similar bodyweight were selected from each of three litters. The pigs chosen were then allotted to treatment randomly within sex and litter. Each protein sequence was fed to a total of three barrows and three gilts in each trial.

In addition to collection of carcass data previously described, the specific gravity of the trimmed right ham was obtained from the weight of the ham in air, divided by the difference of the weight in air and the weight in water. Muscles and fat of the ham were then separated carefully by using a scalpel. The percentage of fresh weight as muscle and as fat was calculated on the basis of the weight of the intact ham. Color of ham and loin was scored by two observers according to Wisconsin Agricultural Experiment Station Bulletin, 1963.

Muscle tissue dissected from the right ham was prepared for moisture, ether extract and protein determination. A section of the *longissimus dorsi* between the 10th and 12th ribs was used for moisture and ether extract determination. Samples were prepared and analyzed according to A.O.A.C. (1960) methods.

A group of 10 students and professors, ranging in age from 22 to 30 years, constituted the taste panel. The meat used by the panel was a previously frozen section of right loin from the 4th to the 10th rib. The loin was thawed at 36° F for 48 hr. and then roasted at a constant temperature of 350° F until the meat thermometer reached 185° F. A section 1.5 in. thick was cut from the posterior end of the loin for Warner-Bratzler shear evaluation. Three, 0.5-in. diameter cores of lean meat were obtained from this 1.5-in. section, and three readings were made on each core. The shear value was calculated from the average of the nine readings from each loin. The meat for taste acceptability was cut in cubes approximately 0.4 in.³ from the central portion of the loin, and throughout the panel each member received meat from the same relative position in each loin. Each member was asked to score the desirability of meat on four attributes, tenderness, juiciness, flavor and overall acceptability. Each attribute was scored from 1 to 8; 1 representing extreme undesirability, and 8 extreme desirability. The taste score was calculated from the average scores of the 10 members.

Data from the two trials were pooled after homogeneity of variance was tested (Steel and Torrie, 1960). Duncan's multiple-range test was applied to compare treatment means (Steel and Torrie, 1960).

Results and Discussion

EFFECTS ON CARCASS COMPOSITION

Results of the five trials are generally in agreement. Increasing dietary protein increased yield of lean cuts and decreased per cent fat cuts. It appeared that lean cuts from carcasses of pigs fed either the high- or medium-protein diets contained a higher proportion of lean than similar cuts from carcasses of pigs fed the low-protein diet. Bellis and Taylor (1961) found such a relationship.

Trial 1

The carcasses in this trial were less meaty than the market now demands. For example, only three of the pigs had *longissimus dorsi* muscles measuring 4 sq. in. or more and, based on U.S.D.A. standards, there were only five U. S. No. 1 carcasses. Despite this, there were responses to the protein levels used. Carcasses from pigs fed either the medium- or high-protein rations yielded a greater ($P < .01$) per cent of lean cuts than those fed the low-protein ration (Table 3). Differences between the carcasses of pigs fed the high- and medium-protein levels were slight. Carcasses from gilts yielded a greater ($P < .01$) percentage of lean cuts than barrows.

Carcasses from pigs fed either high- or medium-protein ration yielded a smaller ($P < .05$) proportion of fat cuts (belly, jowl, leaf fat, fat-back and fat trim) than those from the pigs fed the low-protein ration.

TABLE 3
Effect of Dietary Protein Level and Sex on Carcasses of Twelve
200-Lb. Durocs. Trial 1

	Protein level ^a			Sex ^b	
	High	Medium	Low	Gilts	Barrows
Per cent lean cuts	52.7	52.9	50.8**	54.5**	49.8
Per cent fat cuts	35.0	35.5	38.3*	33.4	39.1**
L. dorsi area, sq. in.	3.9	3.7	3.5	4.1**	3.4
Average backfat thickness, in.	1.5	1.5	1.8*	1.4**	1.7

*($P < .05$).

**($P < .01$).

^a4 animals per mean.

^b6 animals per mean.

Explanation: " $P < .05$ " is called a "probability statement" and it means that the odds are less than 5 in 100 that these differences among the means (averages) would have occurred by chance alone.

The difference due to sex was significant ($P < .01$), with the gilt carcasses containing less fat cuts than the barrow carcasses.

Cross-sectional area of the *longissimus dorsi* muscle increased with dietary protein level and the cross-sectional area of *longissimus dorsi* muscles was greater ($P < .01$) for gilts than for barrows.

Average backfat thickness was decreased ($P < .05$) with the first 3 per cent increase in dietary protein level but the second increase did not appear to have further influence. The average backfat thickness of gilt carcasses was less ($P < .01$) than that of barrow carcasses.

Trial 2

Per cent lean cuts was non-significantly greater for pigs fed the medium- and high-protein levels (Table 4) than for the low group.

TABLE 4
Effect of Dietary Protein Level, Sex and Strain on Carcasses of Eleven¹ 200-Lb. Pigs. Trial 2

	Protein level			Sex		Strain	
	High	Medium	Low	Gilts	Barrows	York-shires	Cross-breds
Per cent lean cuts	54.2	54.7	52.2	53.8	53.5	50.8	56.9**
Per cent fat cuts	33.6	32.9	34.8	32.8	34.9	36.3	30.7**
L. dorsi area, sq. in.	5.0	4.6	4.4	5.0*	4.2	4.3*	5.1
Average backfat thickness, in.	1.29	1.33	1.38	1.28	1.40	1.49**	1.15

*($P < .05$).

**($P < .01$).

¹Data missing for one crossbred barrow on high protein.

There was no appreciable differences due to sex. In trial 1 the gilt carcasses had a significantly greater ($P < .01$) proportion of lean cuts than the barrow carcasses. This is in agreement with Bruner *et al.* (1958) and Cahill *et al.* (1960). The lack of a significant difference between barrows and gilts in trial 2 may be associated with confinement of the barrows in metabolism crates since this led to food restriction (vide infra). The carcasses from the crossbred pigs yielded a greater ($P < .01$) proportion of lean cuts than those from the Yorkshires.

Gilts had larger ($P < .05$) *longissimus dorsi* area than barrows. Also, crossbreds had larger ($P < .05$) *longissimus dorsi* area than Yorkshires. The effect of protein level was less evident.

Trial 3

The pigs in trial 3 did not grow as rapidly as those in previous trials. This was partly due to bacterial scours in the early part of the trial and to several weeks of sub-freezing weather.

Increasing dietary protein level increased the per cent lean cuts from carcasses of pigs slaughtered at 200 lb. (Table 5). Those fed the high and medium rations did not differ significantly from each other. Gilt carcasses yielded a greater ($P < .05$) proportion of lean cuts than barrow carcasses.

At 75 and 125 lb., per cent lean cuts varied directly with dietary protein levels, but differences were small compared to the standard deviations of the means. Four of the six gilts slaughtered at 125 lb. had *longissimus dorsi* muscles measuring in excess of 4 sq. in.

The second increase in dietary protein resulted in a significant ($P < .01$) decrease in per cent ether extract of the 10th to 12th rib section of the *longissimus dorsi* muscle of carcasses of 200-lb. pigs (Table 6). The *longissimus dorsi* muscle sections from gilt carcasses contained a smaller

TABLE 5
Effect of Dietary Protein Level and Sex on Carcasses
of Thirty-Six Pigs. Trial 3

	Protein level						Sex			
	High		Medium		Low		Gilts		Barrows	
Per cent	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
lean cuts										
200 lb.	53.6		52.5		50.4*		53.1*		51.2	
125 lb.	56.6	2.9	56.3	1.5	55.3	2.8	57.1	2.5	55.0	1.6
75 lb.	60.4	1.0	59.4	0.9	58.2	1.2				
Per cent fat cuts										
200 lb.	34.3		34.1		37.1		34.1*		36.2	
125 lb.	27.2	3.0	27.8	1.6	27.7	1.4	26.0	1.4	29.0	0.8
75 lb.	22.9	0.6	26.7	2.0	27.6	2.0				
L. dorsi area, sq. in.										
200 lb.			4.6		4.2		4.7*		4.1	
125 lb.	3.9	0.5	3.6	0.5	3.6	0.5	4.0	0.5	3.4	0.4
75 lb.	2.7	0.3	2.7	0.4	2.6	0.1				
Average backfat thickness, in.										
200 lb.	1.3		1.2		1.5*		1.3*		1.4	
125 lb.	1.0*	0.05	1.0	0.10	1.1	0.10	1.0*	0.15	1.0	0.02

*($P < .05$).

*Data missing for one crossbred gilt on high protein at 125 lbs.

($P < 0.1$) per cent ether extract than those from barrow carcasses and those from Durocs contained more ($P < .01$) ether extract than those from crossbreds. At 125 and 75 lb. ether extract varied with treatment.

Kauffman (1960) indicated that marbling (measured in this trial as ether extract) is one of the most important factors influencing eating quality of pork. Ether extract varied inversely with protein level; however, ether extract was influenced more by strain than by diet. Should protein level be increased in practice, it may still be possible to maintain adequate marbling by selection.

Gain in lean cuts (Table 6) could be estimated for each period in trial 3. Gain in lean cuts varied directly with dietary protein level in the first and last periods but from 75 to 125 lb. there was a significant ($P < .01$) inverse relationship. From 75 to 200 lb. the gilts gained more in lean cuts than the barrows and this difference was significant ($P < .01$) for the period from 75 to 125 lb.

Protein level did not affect weight of heart, amount of total nitrogen per milliliter of blood serum, or red cell count. There was a non-significant tendency for 75-lb. pigs to have higher N levels in the serum than older pigs. Weights of livers from 200-lb. pigs fed the high-protein ration were heavier than those from pigs fed either the medium- or low-protein ration. Robison (ca. 1928) found that protein level influenced liver weights.

Trials 4 and 5

With the higher protein levels, the pigs had leaner carcasses with less backfat, larger *longissimus dorsi* muscle areas, a greater percentage of lean cuts, a lower proportion of fat cuts and a higher percentage of separable ham muscle (Table 7).

The specific gravity of the trimmed ham appeared to be a valid index for measuring carcass leanness. A significant linear relationship existed between the specific gravity of the trimmed ham and the per cent of lean cuts ($r = 0.68$, $P < .01$), the per cent of fat cuts ($r = -.70$, $P < .01$), the percentage of separable muscle of the ham ($r = 0.59$, $P < .01$), and the percentage of separable fat of the ham ($r = -.64$, $P < .01$). Standal (1965) reported that specific gravity of the hams was the most potent single variable for predicting per cent lean ($r = 0.80$) and per cent fat ($r = -.83$) in the hams. Brown *et al.* (1951) and Holme *et al.* (1963) used specific gravity of the carcass as a measure of fatness or leanness.

The color score was not significantly different among treatments.

TABLE 6

Effects of Dietary Protein Level, Sex and Strain on Per Cent Ether Extract of 10-12th Rib Section of LONGISSIMUS DORSI Muscle and Gain in Lean Cuts. Trial 3

Ether extract	Sex																				
	Protein level				Gilts				Barrows				Strain								
	High		Medium		Low		Mean		Std. dev.		Mean		Std. dev.		Crossbreds		Durocs				
200 lb.	Mean	5.9**	Std. dev.	9.0	Mean	8.9	Std. dev.	2.3	Mean	7.0**	Std. dev.	2.7	Mean	8.8	Std. dev.	3.1	Mean	5.9**	Std. dev.	11.9	
125 lb.	Mean	4.3	Std. dev.	5.3	Mean	6.1	Std. dev.	2.3	Mean	4.5	Std. dev.	2.7	Mean	5.9	Std. dev.	3.1	Mean	3.4	Std. dev.	1.1	7.1
75 lb.	Mean	3.3	Std. dev.	4.0	Mean	4.8	Std. dev.	1.8	Mean	4.5	Std. dev.	2.7	Mean	5.9	Std. dev.	3.1	Mean	2.6	Std. dev.	0.2	5.4
Gain in lean cuts, lb.																					
40-75 lb.	Mean	14.3	Std. dev.	13.4	Mean	13.3	Std. dev.	13.3	Mean	12.5**	Std. dev.	15.4	Mean	15.4	Std. dev.	12.4**	Mean	12.4**	Std. dev.	16.9	16.9
75-125 lb.	Mean	15.9**	Std. dev.	18.1	Mean	18.8	Std. dev.	18.8	Mean	19.0**	Std. dev.	16.2	Mean	16.2	Std. dev.	16.6**	Mean	16.6**	Std. dev.	19.2	19.2
125-200 lb.	Mean	27.4	Std. dev.	25.6	Mean	24.8	Std. dev.	24.8	Mean	26.4	Std. dev.	25.5	Mean	25.5	Std. dev.	25.9	Mean	25.9	Std. dev.	26.0	26.0
40-200 lb.	Mean	59.9	Std. dev.	59.1	Mean	57.6	Std. dev.	57.6	Mean	60.0	Std. dev.	57.8	Mean	57.8	Std. dev.	56.9	Mean	56.9	Std. dev.	62.8	62.8

**($P < .01$).

TABLE 7

The Effect of Dietary Protein Level on Feedlot Performance and Carcass Characteristics

Items	Protein level		
	High	Medium	Low
No. of animals	12	12	12
Initial wt., lb.	53.6	56.9	55.3
Final wt., lb.	203.5	202.9	203.3
Days on trial	93.3 ^a	92.0 ^a	102.5 ^b
Daily gain, lb.	1.61 ^a	1.59 ^a	1.43 ^b
Feed consumption, lb.	523 ^a	551 ^{a,b}	571 ^b
Feed consumed/gain in wt.	3.48 ^a	3.77 ^{a,b}	3.87 ^b
Feed consumed/gain in lean cuts	9.02 ^a	9.83 ^{a,b}	10.28 ^b
Protein consumption, lb.	86.4 ^{a,c}	74.3 ^{b,e}	59.8 ^d
Protein consumed/gain in wt.	0.58 ^{a,c}	0.51 ^b	0.40 ^{a,d}
Protein consumed/gain in lean cuts	1.49 ^c	1.23 ^a	1.00 ^{b,d}
Dressing, %	73.6	74.0	74.8
Carcass length, in.	28.9	28.5	29.0
Backfat thickness, in.	1.34	1.42	1.50
L. dorsi area, in. ²	4.43 ^a	4.17 ^{a,b}	3.80 ^b
Lean cuts % (carcass basis)	53.4 ^a	51.6 ^{a,b}	50.3 ^b
Lean cuts, % (live wt. basis)	39.6 ^a	38.6 ^{a,b}	37.8 ^b
Fat cuts, % (carcass basis)	34.9 ^c	37.2 ^a	38.3 ^{b,d}
Fat cuts, % (live wt. basis)	26.0 ^a	27.8 ^{a,b}	28.8 ^b
Specific gravity of trimmed right ham	1.062 ^c	1.061 ^c	1.057 ^d
Separable muscle of the trimmed ham, %	64.2 ^c	62.0 ^{c,d}	60.2 ^d
Separable fat of the trimmed ham, %	21.2 ^a	22.4 ^{a,b}	24.7 ^b

^{a,b}Data on the same line bearing different superscript letters differ significantly ($P < .05$).

^{c,d}Data on the same line bearing different superscript letters differ significantly ($P < .01$).

The ether extract of the *longissimus dorsi* and of the muscle of the trimmed right ham varied inversely with the protein level ($P < .01$). The differences observed in the contents of crude protein and ash were not significant, if corrected to a fat-free basis (Table 8). Vipperman *et al.* (1963) pointed out that an increase in moisture and ash in the muscle is accomplished by a decrease in fat. A.S.A.P. (1963) observed that the chemical composition of fat-free mature animals is practically constant.

The results of the taste desirability and shear evaluation are shown in Table 9. Only tenderness of the meat was detected to be significantly

TABLE 8
The Effect of Dietary Protein on Chemical Composition of
Right Ham Muscles and L. DORSI

Items	Protein level		
	High	Medium	Low
No. of animals	12	12	12
Ham muscles; fresh basis			
Moisture, %	72.7 ^a	72.3 ^{a,b}	71.7 ^b
Ether extract, %	5.81 ^{a,c}	6.66 ^{b,c}	7.92 ^d
Protein, %	21.0 ^a	21.0 ^a	20.1 ^b
Ash, %	1.06 ^{a,c}	1.02 ^b	1.01 ^d
Ham muscles; fat free basis			
Moisture, %	77.2 ^a	77.5 ^{a,b}	77.9 ^b
Protein, %	22.3	22.5	21.9
Ash, %	1.12	1.09	1.10
L. dorsi			
Moisture, %	71.1 ^{a,c}	70.2 ^b	69.3 ^{a,d}
Ether extract (dry matter basis), %	19.8 ^c	25.0 ^d	31.0 ^e

^{a,b}Data on the same line bearing different superscript letters differ significantly ($P < .05$).

^{c,d,e}Data on the same line bearing different superscript letters differ significantly ($P < .01$).

TABLE 9
The Effect of Dietary Protein Level on Shear Value and Taste
Panel Evaluation of 4th to 10th Rib Section of Right Loin

Items	Protein level		
	High	Medium	Low
No. of animals	12	12	12
Shear reading, lb.	5.98	6.02	5.20
Tenderness score	5.43 ^c	5.63 ^c	5.93 ^{b,d}
Juiciness score	5.00	5.23	5.28
Flavor score	5.73	5.93	5.77
Overall score	5.56	5.72	5.78

^{a,b}Data on the same line bearing different superscript letters differ significantly ($P < .05$).

^{c,d}Data on the same line bearing different superscript letters differ significantly ($P < .01$).

different ($P < .05$ between the medium- and low-protein groups, and $P < .01$ between the high- and low-groups). There was a tendency to favor the meat from the pigs fed low-protein diets. There were significant correlations between tenderness and other items. The partial correlation

coefficients between tenderness and juiciness, flavor, overall score and shear force reading are 0.48, 0.14, 0.72, -0.68 , respectively. Kauffman *et al.* (1964) indicated that an increase in intramuscular fat in pork improved the flavor, tenderness and juiciness of the cooked pork. Henry *et al.* (1963) pointed out that the tenderness of pork was highly correlated with intramuscular fat ($r = 0.37$) and with juiciness ($r = 0.63$), and intramuscular fat was slightly correlated with flavor ($r = 0.23$). In this experiment, the ether extract content was significantly correlated with juiciness ($r = 0.56$) and overall score ($r = 0.34$). The data suggest that selection for intramuscular fat and other quality traits might well be included in indexes so that inadequate intramuscular fat does not result when the use of high-protein diets is economical.

EFFECTS ON GAIN AND EFFICIENCY

Trials 1 and 2

Data are summarized in Table 10. Differences in feed efficiency were significant ($P < .05$) in trial 2.

Results of the classical nitrogen balance study in trial 2 are shown in Table 11. Except for the second period, the high-protein barrows retained the most nitrogen, whereas the low-protein barrows retained the highest proportion of the apparently absorbed nitrogen. (In the second period high ambient temperatures caused reduced feed intake, especially in low- and high-protein pigs.)

TABLE 10
Effect of Dietary Protein Level on Gain and Efficiency Measures.
Trials 1 and 2

	Protein level					
	High		Medium		Low	
	Trial 1	Trial 2 ^a	Trial 1	Trial 2	Trial 1	Trial 2
Av. daily gain, lb.	1.5	1.7	1.5	1.5	1.4	1.4
Feed per pound gain, lb.	3.5	3.0	3.3	3.3	3.5	3.6
Feed per pound gain lean cuts, lb.	9.6	7.6	9.2	8.3	9.9	9.5
Protein per pound gain lean cuts, lb.	1.71	1.34	1.36	1.25	1.21	1.10
Partial efficiency coefficients			Trial 1		Trial 2	
First increment			+19.7%		+19.9%	
Second increment			+ 3.9%		+32.9%	

^aData missing for one crossbred barrow on high protein.

TABLE 11
Effect of Dietary Protein Level on Nitrogen Retention
in Six^a Barrows. Trial 2

	Pigs per item	Protein level			Difference required for significance at the 5% level of probability
		High	Medium	Low	
Nitrogen retained, grams per day at:					
85 lb.	2	13.4 ^a	11.6	10.6	9.2
120 lb.	2	8.4	13.5*	7.4	4.1
170 lb.	2	16.4 ^a	14.2	7.7	19.6
Per cent of apparently digested nitrogen retained at:					
85 lb.	2	33.8 ^a	41.8	39.4	13.8
120 lb.	2	24.1	34.3	30.5	10.2
170 lb.	2	35.4 ^a	36.6	28.9	24.7

*($P < .05$).

^aData missing for one crossbred barrow at 85 and 170 pounds.

The major limitations of nitrogen balance by the slaughter method appear to be (1) possible sampling errors in estimating the initial composition of experimental animals and (2) the cost of separating cuts into lean and fat tissue or of grinding the entire carcass. The slaughter balance method has a great advantage in that performance of the pigs is not influenced by the restraint and reduced feed intake associated with the classical nitrogen balance technique.

The validity of the classical nitrogen balance technique for determining dietary protein requirements for growing-finishing swine is questionable for the purpose of this experiment. Under the conditions of the experiment it was impossible to get any restrained animal to ingest as much feed as self-fed, unrestrained pigs. It is generally accepted that efficiency of protein utilization is influenced by level of protein intake. Therefore, protein requirements determined by pigs fed a limited amount of feed would not be directly applicable to unrestrained pigs fed *ad libitum*.

A related limitation of the classical balance study is the possible effect on carcass composition. In trial 2 the barrows, which were periodically confined in metabolism crates, produced carcasses which did not differ significantly from littermate gilts receiving the same diet from self feeders. Gilt carcasses would be expected to yield a greater proportion of lean cuts than barrow carcasses (Cahill *et al.*, 1960 and Bruner *et al.*, 1958; also results of trials 1 and 3 of this study).

McMeekan (1940) and Clausen (1959) found that restricted energy intake will influence carcass composition and it is possible that restriction of feed intake was the only causative factor imposed by restraint in metabolism crates. Mitchell (1939) and Lassiter *et al.* (1956) found inconsistencies between growth and balance studies.

In the trial reported here, feed efficiency was lower during the collection period than when pigs were not restrained. It appears that classical nitrogen balance should not be relied upon for extrapolation to carcass traits of *ad libitum*-fed pigs if restraint must be incorporated (cf. Becker and Harnisch, 1958).

The effect of periodic restraint of 2 barrows and 3 gilts compared to an unrestrained littermate pair was tested in a separate mock collection trial using 10 crossbred pigs from a single litter. Lean cuts averaged 52.9 per cent for the restrained animals and 50.9 per cent for controls. This difference was not significant, perhaps because it was not possible to kill the pigs at identical weights. However, when adjusted by covariance for difference in slaughter weight, confinement caused a significant ($P < .01$) reduction in fat cuts.

The partial efficiency coefficient for the second increment of ration protein in trial 2 (Table 10) cannot be adequately explained.

Trial 3

The outcome of trial 3 may have been influenced by slaughtering the first pigs to reach 75 or 125 lb. The most rapidly growing pigs were not allowed to reach market weight, thus influencing average daily gain (Table 12). This situation existed for all treatments. The difference in strain in the beginning was expected since starting weights were not the same.

TABLE 12
Effect of Dietary Protein Level, Sex and Strain on Average Daily Gain, Lb. Trial 3

Weight Range, lb.	Protein level			Sex		Strain	
	High	Medium	Low	Gilts	Barrows	Crossbreds	Durocs
40- 75	1.09	1.08	1.02	1.03	1.09	1.13**	0.98
75-125	1.55	1.48	1.48	1.43	1.57	1.59	1.38
125-200	1.52	1.70	1.47	1.56	1.56	1.61	1.45
50-200	1.34	1.43	1.30	1.34	1.39	1.44	1.29

**($P < .01$).

Pounds of feed required per lb. gain (Table 13) was not significantly different. Pounds protein required per lb. gain in lean cuts (Table 14) was significantly ($P < .01$) different for treatment and for sex. Protein consumed per pound gain varied directly with dietary protein level.

TABLE 13
Effect of Dietary Protein Level, Sex and Strain on Feed
Required Per Pound Gain. Trial 3

	Protein level		
	High	Medium	Low
Pounds feed per pound gain:			
Av. by treatment, sex and strain:			
Crossbred gilts			
50-200 lb.	3.48	3.34	4.06
Crossbred barrows			
50-200 lb.	3.34	3.37	3.74
Duroc gilts			
30-200 lb.	3.60	3.80	3.50
Duroc barrows			
30-200 lb.	3.50	3.50	3.60

TABLE 14
Effect of Dietary Protein Level, Sex and Strain on Pounds Dietary
Protein Required Per Pound Gain in Lean Cuts and on Partial
Efficiency Coefficients of Thirty-Six Pigs. Trial 3

	Protein level**		
	High	Medium	Low
Crossbred gilts			
50-200 lb.	1.53	1.25	1.15
Crossbred barrows			
50-200 lb.	1.46	1.27	1.18
Duroc gilts			
30-200 lb.	1.57	1.39	1.09
Duroc barrows			
30-200 lb.	1.63	1.47	1.16
	Duroc		Crossbred
Partial efficiency coefficients			
First increment	+19.8%		+12.2%
Second increment	+ 5.4%		- 2.7%

**Overall effect of protein significant at 1 per cent level.

Pounds of feed required per pound gain in lean cuts were 8.8, 9.2, and 9.9 for high, medium, and low, respectively, but these were not significantly different. (These values include lean cuts of pigs killed at light weights as well as those killed at 200 lb., but the pigs in the trial grew more slowly and were less efficient than usual.)

Trials 4 and 5

Pigs on the higher protein levels had more rapid rates of gain, improved feed efficiency and consumed significantly less feed per pound gain in lean cuts (Table 7).

General. Gain in lean cuts varied directly with dietary protein level but conformed to the concept of diminishing returns. Protein per pound gain (protein efficiency ratio) was lowest for the low-protein regimen. However, feed per pound gain in lean cuts was highest for the low-protein regimen. Despite the lack of significance in trials 1-3 with the number of animals studied, the latter measure merits attention. Admittedly, belly, jowl, etc. have economic value and a market may fail to make full compensation for the increased meatiness of carcasses from high-protein-fed pigs.

A physical rather than economic solution to the ration protein (input) : carcass protein (output) problem is elusive. Perhaps it is impossible unless a minimum partial efficiency coefficient is specified in lieu of the classical "point of diminishing returns" in which input and output are equated in dollars.

Although the physiologically optimal protein levels may be higher than the high-protein diets used in this study, the economically optimal level probably is below this point. Some workers (*e. g.* Wagner *et al.*, 1963) have reported that higher protein levels also reduce the rate of gain which would result in added costs. In no case did the pigs fed the low-protein diet make the most economical gains at 1961 feed ingredient prices. Moreover, if feed cost per pound gain in lean cuts is taken as the criterion, the low-protein level appears even less favorable.

In order to have large differences between treatment effects in this study the protein level of the various diets differed by three percentage points and, to keep the number of rations to a minimum, the dietary protein level was reduced by three percentage points each period. Perhaps smaller changes would be more in keeping with the pigs' physiological protein requirements. Changes of two percentage points may be acceptable to the feeder and the feed manufacturer.

Summary

Five slaughter balance trials involving 108 weaned pigs were conducted to estimate the influence of three sequences of protein upon gain in trimmed lean cuts. The improvement in carcass merit was greatest for the first increment of ration protein and a tentative recommendation of 18 per cent, 15 per cent, 12 per cent crude protein for the periods weaning to 75 lb., 75 to 125 lb. and 125 to 200 lb., respectively, is offered.

The following changes were associated with increasing protein level; increased yield of lean cuts, increased *longissimus dorsi* muscle area, decreased yield of fat cuts, decreased backfat thickness and decreased ether extract of *longissimus dorsi* muscle.

The interactions between sex and protein level were significant in several instances and this, plus the well-known carcass differences, suggests that gilts may be able to utilize more protein, at a given level of efficiency, than barrows.

The changes in efficiency of production of lean cuts by pigs fed different levels of protein are presented and discussed. The increased gain in lean cuts associated with high ration protein levels conformed to the concept of diminishing returns. Decreased partial efficiency coefficients were obtained in 3 of 4 comparisons. This was reflected in decreased protein efficiency ratios. What may be more important is the fact that the feed required per pound gain in lean cuts continued to decrease as the protein level was increased and feed cost at 1961 ingredient prices followed a similar pattern.

The lowest protein level was associated with more intramuscular fat and greater tenderness of the meat. Selection for adequate intramuscular fat is suggested so that the use of high-protein diets does not lead to lowered product acceptability.

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