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Effects of Energy Supplementation of Corn-oat Rations for Growing-Finishing Swine

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EFFECTS OF ENERGY SUPPLEMENTATION OF CORN-OAT RATIONS FOR GROWING-FINISHING SWINE

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This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

According to the South Dakota Crop and Livestock Reporting Service of the United States Department of Agriculture in 1960 South Dakota ranked third in the nation in the production of oats. Twenty-four percent of all grains produced in South Dakota was oats. The efficient utilization of oats is therefore important. One of the limiting factors in the use of oats for growing pigs is their low available energy.

Animal fats are relatively high in energy. In recent years animal fats have become a surplus item due to their reduced industrial use. This surplus has resulted in low fat prices in relation to other feed ingredients. Feed manufacturers use fat in considerable amounts to reduce dustiness, increase pellet production, and improve the life of pelleting equipment.

Many of the earlier studies with lipids in swine rations were aimed at proving them unnecessary and undesirable. Maynard (1935) stated that there was an absence of any interest in feeding fat to swine, aside from its relation to the soft pork problem, and that the content of this nutrient in rations was determined largely by the demand for fat by manufacturing industries which had established a trend resulting in the removal of fat from feed ingredients. He went on to review numerous studies emphasizing the detrimental effect of fats and fatty constituents as well as the fact that very little was needed in the ration.

The purpose of these studies was to determine whether or not increased energy by the use of animal fat additions would improve the feeding value of rations containing a high level of oats, and if adjustments in protein would be beneficial with this increased energy. Rate of gain, feed efficiency, and carcass evaluations were used in determining this feeding value.

REVIEW OF LITERATURE

Effects of Oats in Growing and Finishing Swine Rations

Cunha (1957) stated that oats were an excellent feed for growing pigs, but the portion of oats making up the rations must be limited due to its fibrous and bulky nature. Smith (1952) listed several factors that influence the value of oats in growing and finishing swine rations. Among these factors were fineness of grind, pelleting, quality and level of oats, as well as size of animal.

Feed efficiency was improved 6 percent when oats with a test weight of 32 pounds was fed as compared to 24-pound oats. This was observed by Jensen *et al*. (1958) when using rations containing 40 percent oats.

Numerous studies have been conducted to determine the best level of oats that can be used in swine rations. Carroll *et al*. (1937) concluded that oats could be fed as approximately one-half of the ration without decreasing gains although the feed required per pound of gain would be increased slightly. Jensen *et al*. (1957, 1958) re-evaluated the use of oats in order to determine their value in modern day rations. Four levels of oats were found to produce a linear decrease in gains and a linear increase in feed required per pound of gain as the oat level increased. In summary, several investigators have shown that as the level of oats increased in swine rations the feed efficiency decreased. These workers also reported that the rate of gain does not seem to be markedly influenced by low levels of oats (Carroll *et al*., 1937; Sewell *et al*., 1957; Jensen *et al*., 1957, 1958, 1959; Wahlstrom, 1959).

Thomke (1960) stated that the nutritive value of oats for pigs was influenced directly by their hull content which is of no nutritive value.

Jensen *et al*. (1957) concluded that the reduction in performance caused by the addition of oats to swine rations was due to the higher fiber content, and thus lower TDN value. After conducting studies with corn oil and oat hull additions, these workers further concluded that the depression of performance resulting from addition of oat hulls to a corn-soybean meal ration could be corrected by the addition of corn oil.

Fat Requirements in Growing and Finishing Swine Rations

Studies by Evans and Burr (1927), Burr and Burr (1929), Duel *et al*. (1950) and Cerecedo *et al*. (1952) showed that a limited amount of fat in the ration was essential for animal growth and health.

Wits and Beeson (1951) reported that pigs definitely needed fat in the ration in order to maintain normal growth and feed efficiency. The typical deficiency symptoms reported to have developed in pigs lacking a dietary source of fat were dermatitis, necrotic lesions of the skin, general unthriftiness, retarded sexual maturity, underdeveloped digestive systems, and small gall bladders. Although the exact level of fat and/or fatty constituents needed in swine rations was not determined, a level of 1.0 to 1.5 percent of either vegetable or animal fat was reported to be adequate and, therefore, it was concluded that practical swine rations should supply enough fat for growing-finishing pigs.

Performance of Swine Fed Growing and Finishing Rations with Supplemental Fat

Hillier (1950) studied the influence of various levels of fat on the rate and economy of gain. He fed one basic ration consisting of degermed corn, alfalfa leaf meal, solvent processed soybean meal, fish meal, yeast, bone meal, salt and delsterol (a vitamin D supplement). Rations for the growing and finishing periods were balanced to 18 percent and 14 percent crude protein, respectively. In the first trial lard was mixed in three of the four rations at 2, 6, and 10 percent levels. Six grams of thyroprotein were also added to every 100 pounds of ration. Hillier reported that all rations were very satisfactory. Improvement in gains and feed efficiency were observed as the fat level increased. In two other similar trials, in which tallow was used instead of lard, the higher energy rations also produced faster gains on less total energy.

Perry <u>et al</u>. (1953) used stabilized lard at seven levels, 1, 2, 3, 4, 6, 8 and 10 percent, to replace corn in a balanced drylot ration. Levels of 1 to 4 percent added fat were reported to have no significant effect on feed efficiency. However, 10 percent less feed was required when either 8 or 10 percent lard was used. The average daily gains in all lots were similar.

Heitman (1956) studied swine responses to rations which included 5 or 10 percent levels of stabilized tallow or 10 percent stabilized lard. These rations, fed in three drylot trials, included barley and a mixed protein supplement which was adjusted to equalize the calorie-

protein ratios. Tallow increased weight gains significantly in all cases, but the addition of 10 percent lard did not improve growth. Feed consumption was not consistently affected by the addition of either lard or tallow. Feed utilization was improved in the second and third trials by tallow and lard additions to the ration. Heitman concluded that the difference in calculated TDN content could have accounted for this improved feed utilization.

Sewell _et al_. (1957) reported that there were no significant differences in growth resulting from the addition of 5 percent tallow to a fortified corn-soybean meal ration. However, there was a significant increase in efficiency of feed utilization.

Barrick _et al_. (1953) conducted two experiments in which the effects of fats from animal and plant sources were evaluated. In the first experiment three rations were compared. The variables were 10 percent peanut oil, 10 percent beef fat and a 10 percent half and half mixture of these two fats. Rate of gain and feed efficiency were reported to be similar for pigs receiving the various rations containing fat; however, the pigs receiving the ration with no added fat gained only 2.02 pounds per day compared with 2.34 pounds per day for the pigs on the fat rations. The pigs receiving the ration with no added fat consumed 347 pounds of feed compared with an average of 284 pounds of feed per 100 pounds of gain for the pigs in lots receiving added fat. In the second experiment two animal fats and two plant oils were compared at 10 percent levels. Both the animal fats (beef fat and grease) and only one of the vegetable oils (cocoanut oil) improved gains and

feed efficiency when compared with the control lot with no added fat. The addition of soybean oil to the ration resulted only in improved feed efficiency.

Day et al. (1953) studied the value of adding animal fats to swine rations and the value of some feed additives in conjunction with fats. The feed additives were two surface active agents, Armour's Ethomid C/15 alpha ethylene oxide coco amine at 0.5 percent and Arquad HT-16, a quaternary ammonium salt at 0.25 percent and choline chloride at 0.1 percent. The fat was added as 10 percent lard. The average daily gains were increased 0.18 and 0.27 pound by the addition of the surface active agents and lard, respectively. The feed required per 100 pounds of gain was reduced 50 pounds by the addition of lard. Adding surface active agents or choline to rations containing lard did not improve either the rate of gain or feed efficiency.

In four Florida experiments conducted to determine the feeding value of beef fat in swine rations, Kropf et al. (1954) reported that the addition of 10 or 15 percent tallow to the basal ration improved gains and efficiency of gains. Adding B-vitamins resulted in a further improvement in the ration. When the fat was hand-fed on a free-choice basis with a low-fat ration pigs consumed 18 percent fat. The growth of pigs fed fat free-choice was slower than that of pigs receiving a ration with added fat.

Scott (1957) reported the effect of furazolidone, chlortetracycline, and animal fat on the performance of growing-finishing swine. When animal fat was added to the rations without furazolidone and

chlortetracycline slower growth resulted. However, with the addition of either of these additives slower growth was not noted, and in some cases growth was stimulated. Feed efficiency was found to be significantly improved by the addition of 10 percent fat whereas chlortetracycline appeared to have no effect.

Sewell et al. (1958) studied the effects of adding a choleretic agent, Gallogen, to 18 percent protein fortified corn-soybean meal rations containing three levels of fat. They reported that increasing the fat level by the addition of either 5 or 10 percent stabilized tallow to the two rations resulted in a significant increase in growth. These studies showed that as the level of dietary fat increased the fecal-ether-extractable material also increased. It wasn't until the end of the eight-week trial that a significant decrease in the percentage of fecal-ether-extract was observed with the Gallogen supplemented diets.

Aubel and Richardson (1954) conducted two experiments with inedible animal fat added to the protein supplement by means of using high and low-fat tankage. The high-fat supplement analyzed 27 percent protein. In the first experiment shelled corn was used with the supplement, and pigs had access to pasture. The rate of gain was similar on both supplements and the feed consumed was practically the same. Pigs ate less corn and 66 percent more supplement per 100 pounds of gain with the fat added to the supplement. In a winter experiment the same supplements were used but milo replaced corn as the grain. Daily gains of pigs fed rations with fat added to the supplement were

about 6 percent less than the gains of pigs not fed the high-fat supplement. Both the low and high-fat supplement-fed lots consumed the same amount of milo per hundred pounds of body weight gain. In this experiment, as in the other, more high-fat supplement was required to produce 100 pounds of gain.

Sheffy et al. (1955) conducted two experiments with different levels of waste animal fat fed in combination with variable levels of roughage in order to maintain equal available energy. The protein level was the same in all rations. Growth, feed efficiency, carcass quality, and ration digestibility were used as criteria of evaluation. Improvement in rate of gain and feed efficiency was noted when 3 percent of yellow grease and 12.5 percent of roughage were fed and compared with the control ration containing no added fat and 5 percent roughage. Roughage content over 12.5 percent resulted in slower growth even when the energy content of the ration was kept constant by the addition of fat. Digestibility of the dry matter, crude protein and crude fiber decreased as the levels of fat and roughage increased. The firmness of the carcasses tended to decrease as the levels of fat and roughage increased.

With 553 pigs used in forty-five comparisons (Table 1) animal fat additions averaging 8.4 percent improved the rate of gain an average of 4.9 percent. Also, the efficiency of feed utilization was improved an average of 10.6 percent by the addition of fat. Feed consumption was 6.4 percent lower with the fat rations. An average of 1 pound of fat was computed to be equal to 2.26 pounds of ingredient.

Table 1. Experimental Data on Animal Fat in Rations for Swine

Reference	No. pigs per ration	Level of added fat	Type of animal fat	Daily gain lbs.	Daily feed lbs.	Feed efficiency lbs./cwt.	Percentage change due to fat addition: Daily gain %	Daily feed %	Feed efficiency %
Hillier(1950)	8	0		1.73	6.43	372			
		2	pork	1.78	6.25	351	3	- 3	5
		6	pork	1.80	6.07	337	4	- 6	9
		10	pork	1.90	5.86	309	10	- 9	17
		0		1.73	6.13	354			
		10	beef	1.83	5.02	274	6	-18	23
Day(1953)	11	0		1.71	6.19	362			
		10	lard	1.89	6.17	312	16	0	14
		0		1.89	6.99	370			
		10	lard	1.98	6.24	325	5	- 8	12
Perry(1953)	12	0		1.59	4.72	298			
		1	lard	1.59	4.93	309	0	4	- 4
		2	lard	1.48	4.44	301	- 7	- 6	- 1
		3	lard	1.42	4.26	300	-11	-10	- 1
		4	lard	1.46	4.40	301	- 8	- 7	- 1
		6	lard	1.41	3.93	278	-11	-17	7
		8	lard	1.59	4.22	267	0	-11	10
		10	lard	1.51	4.04	268	- 5	-14	10
Barrick(1954)	N.R.[a]	0		2.02	7.01	347			
		10	beef	2.30	6.42	279	14	- 8	20
		0		1.57	5.68	360			
		10	beef	1.76	5.02	286	12	-12	21
		10	grease	1.67	4.84	291	6	-15	19
Kropf(1954)	4	0		1.24	5.41	436			
		10	beef	1.23	5.02	408	1	- 7	6
	5	0		0.91	4 88	536			
		10	beef	1.32	5.29	401	45	8	25
	7	0		1.37	5.00	365			
		10	beef	1.42	4.88	344	4	- 2	6
Heitman(1956)	20	0		1.60	4.63	289			
		10	tallow	1.98	6.26	316	24	35	- 9
	10	0		1.75	5.96	341			
		5	tallow	1.85	6.21	335	6	4	2
		10	tallow	2.05	6.36	310	17	7	9
	10	0		1.64	6.36	389			
		10	lard	1.68	5.08	302	2	-20	22
		10	tallow	1.75	5.42	309	7	-15	21
Gesler(1957)	6	0		1.51	6.16	408			
		10	N.R.[a]	1.68	5.81	346	10	- 6	15
Scott(1957)	5	0		1.71	6.43	330			
		10	N.R.[a]	1.49	4.34	291	-13	-23	12
		0		1.75	5.79	331			
		10	N.R.[a]	1.84	5.15	280	5	-11	15
		0		1.71	6.24	365			
		10	N.R.[a]	1.72	5.21	303	1	-17	17
		0		1.78	6.44	362			
		10	N.R.[a]	1.92	5.28	275	- 8	-18	24
Sewell(1957)	10	0		1.53	4.90	320			
		5	tallow	1.62	4.73	292	6	- 3	9
Sewell(1958)	5	0		1.55	5.33	344			
		10	tallow	1.71	4.55	266	10	-15	23
		0		1.60	5.31	332			
		10	tallow	1.63	4.66	286	2	-12	14
		0		1.64	5.48	334			
		10	tallow	1.86	4.85	261	13	-12	22
		0		1.66	5.69	343			
		10	tallow	1.83	4.87	266	10	-14	22
Brooks(1959)	5	0		1.21	3.93	325			
		4	lard	1.22	3.93	322	1	0	1
		8	lard	1.27	3.82	301	5	- 3	7
		12	lard	1.26	3.71	294	4	- 6	10
Perry(1959)	6	0		1.60	4.71	293			
		5	lard	1.79	4.18	269	12	-11	8
		7.5	lard	1.84	4.67	254	15	- 1	13
		10	lard	1.96	4.73	241	22	0	18
		12.5	lard	1.79	4.16	235	12	-12	20
		15	lard	1.85	4.22	299	16	-10	- 2
Pond(1960)	6	0		1.53	4.83	315			
		10	tallow	1.65	4.47	270	8	- 7	14
Bowland(1961)	12	0		1.80	5.70	316			
		15	tallow	1.82	4.60	253	1	-19	20
		0		1.74	5.10	293			
		15	tallow	1.80	4.40	245	3	-14	16
AVERAGE		8.4					4.9	- 6.4	10.6

[a]Not reported.

Swine Carcass Characteristics as Affected by Supplemental Fat in the Ration

After reviewing work done with vegetable and fish oils Ault et al. (1960) stated that to avoid carcass softness, undesirable flavor and odor when feeding fat at even moderately high levels, the fat fed should be somewhat similar to pork fat in composition. It was then concluded that grease and tallow seemed to meet this requirement most closely. Taste panel tests by Heitman (1956) supported this conclusion.

Hillier (1950) reported a tendency toward a lower percentage of lean cuts and a higher percentage of fat cuts in the carcasses of pigs on the high-fat rations. These differences were greater with those pigs from the lots fed pork fat when compared with the lots fed beef fat. Other observations indicated that a 10 percent level of either beef or pork fat resulted in an increased backfat thickness of 0.18 inch.

Barrick et al. (1953), Heitman (1956), and Sewell et al. (1958) also reported significantly more backfat on pigs fed rations containing animal fat. However, Heitman (1956) reasoned that the increased backfat thickness was no more than would be expected because of the greater body weight of these pigs over the controls. Barrick et al. (1953) stated that the percentage primal cuts were not greatly affected by rations containing added fat.

Day et al. (1953) and Kropf et al. (1953) reported that neither backfat nor carcass grade was markedly influenced by the addition of animal fat to the ration. The latter authors observed that when unmixed liquid fat was fed on a free-choice basis with a complete mixed

ration, pigs made unsatisfactory gains, had lower dressing percentage, and greater body length. The liquid fat-fed pigs also had softer carcasses with less backfat.

Sheffy et al. (1955) studied the effect of increasing levels of fat and roughage. They reported that carcass firmness decreased as the level of fat and roughage increased.

Performance of Swine Fed Growing and Finishing Rations with Varying Protein and Energy Levels

Mitchell and Hamilton (1935) stated that there was a relationship between the protein and energy content of the ration. This relationship indicated that an upward adjustment of the protein level was necessary to obtain the full benefit of increased energy in the diet. Hill and Dansky (1954), Combs and Romoser (1955), Matterson et al. (1955), and Sunde (1956) showed a relationship between protein and energy in poultry rations. The results of experiments conducted to study this relationship with swine have been inconsistent. Clawson et al. (1958a) reported no significant differences in the rate of gain or feed efficiency of pigs fed rations containing various protein-energy ratios (21, 26, 29). These workers expressed the protein-energy ratio as total Calories per gram of protein. It was noted that when the pigs used in these trials were smaller, prior to 125 pounds, an increase in protein was necessary in order to realize the full benefit from the added fat. These conclusions were based on two trials in which the energy was largely supplied by corn with added fat levels of 0, 10, and 20 percent. In further experiments of a similar nature Clawson and

Barrick (1958c) used somewhat higher protein-energy ratios (26, 31, 38). Cerelose and animal fat were used to vary the energy. Growth and feed utilization were influenced only slightly in favor of the lower calorie-protein ratios.

Clawson *et al*. (1958b) studied the effects of three levels of protein (18, 15, 12 percent) with 0, 5 and 10 percent fat added to each level of protein. The addition of 10 percent animal fat to rations containing either 18 or 15 percent protein improved growth. The addition of fat to low protein rations depressed growth. It was also noted that the addition of animal fat resulted in improved digestibility of ether-extract and protein while, apparently, exerting no influence on the digestibility of crude fiber or nitrogen-free extract.

Ault *et al*. (1960) reviewed protein-energy relationship as studied by Sewell (1957) and Baird (1957). Ault concluded that a growth depression resulted when low protein rations were fed with added fat. In Sewell's studies higher energy levels were needed to realize the full benefit of additional protein. Feed utilization data from both studies indicated that the greatest efficiency was obtained with the rations containing the highest level of energy and an intermediate level of protein, 8 to 10 percent tallow and 14 to 17 percent protein.

Baird *et al*. (1958) reported that increasing the ration caloric content improved feed efficiency but had no significant effect on growth rate. They concluded from additional studies that significant negative correlations existed between calorie-protein ratio and average daily gain, and between average daily gain and feed efficiency.

Lowrey et al. (1958) conducted a 3 x 2 factorial experiment in which the variables were protein and energy. Pigs were fed from 19 to about 55 pounds body weight. The results indicated that fat additions improved growth and feed utilization of young pigs only when the level of protein was adequate.

Perry et al. (1959) concluded that added animal fat improved gain, lowered feed consumption and improved feed efficiency. It was also concluded that within the range of 14 to 20 percent protein the level of protein had no effect on growth rate or feed efficiency with any of the added fat levels. There was no calorie-protein relationship due to combinations of protein and energy within the ranges studied.

Brooks and Thomas (1959) studied the influence of energy on the protein requirement of the growing pig. They concluded that the protein requirement of the pig does not vary with the energy level if the energy is either increased by adding lard or decreased by higher fiber levels in the ration. The growing rations studied ranged from 14 to 18 percent protein with 6 percent lard and/or a 6 percent increase in fiber.

No protein-fat interactions were found by Mulholland et al. (1960). Added fat had no effect on growth rate, but did improve feed utilization.

Abernathy et al. (1958) conducted an experiment to evaluate protein, lysine and energy interrelationships. The addition of L-lysine hydrochloride resulted in significantly slower gains. This effect of L-lysine on growth was reduced when fat was added to the rations. Other

effects reported were that increased caloric density by fat additions produced linear increases in gains and feed efficiency.

Pond et al. (1960) studied tallow, pantothenic acid and protein interrelationships. Growth was significantly greater with 20 percent growing and 18 percent finishing rations when compared with 12 percent growing and 10 percent finishing rations. An increase in rate of gain was observed with the addition of tallow to the high protein ration but not with the low protein ration. The addition of 10 percent fat decreased feed consumption but increased the total energy intake as measured by TDN. Average energy and protein required per pound of gain were reduced by added fat at both protein levels. Additional pantothenic acid had no effect on any of the criteria measured in these studies.

Bowland (1957), Bowland and Berg (1958) and Beacom (1961) conducted experiments studying protein-energy relationships in rations when the energy was reduced by the use of high levels of fiber. Bowland (1957) conducted experiments in which the energy was varied by the use of different levels of oats and wheat bran. The energy and protein varied from 79 percent TDN and 21 percent protein to 69 percent TDN and 15 percent protein. While the best gains were made with the ration containing the highest energy and the highest protein level, gains with the low energy rations were not improved by the levels of protein used. Feed utilization was improved by the higher energy and protein levels. The author concluded that energy and protein in a ration have a relationship to each other and should not be adjusted

independently.

Bowland and Berg (1958) and Beacom (1961) also reported that rate of gain and feed efficiency were the greatest on the rations containing the highest levels of energy and protein. Data presented by Beacom indicated that increasing the level of either protein or energy increased daily gains and feed efficiency. When both protein and energy were added these beneficial effects were cumulative.

Pond (1958) reported that pigs fed the lower energy rations with two levels of corn cobs grew at a slower rate than those fed the higher energy control ration without corn cobs. The feeding of corn cob rations with a lower level of protein resulted in slower growth, but when no corn cobs were included in the ration growth was almost identical with both protein levels. If the utilization of corn cobs was considered as zero, the feed efficiency of the rest of the ration declined with increased levels of corn cobs on the low protein ration, whereas efficiency improved with the higher protein level. Pond concluded that feed consumption data showed that pigs fed low energy rations did not equalize their energy intake by consuming more feed.

Boenker and Tribble (1960) reported that growth rate was slower when pigs were fed fat and a low level of protein, whereas faster growth was observed with higher protein rations. In general, as the energy level increased the feed efficiency improved, although somewhat greater improvement in feed efficiency occurred with increased energy in the higher protein rations. In these experiments 7 percent fat was added to rations with 13, 16 or 19 percent protein during the growing

period. In similar experiments using rice hulls, Noland and Scott (1960) reported that the protein-energy interaction was highly significant for pigs weighing from 40 to 75 pounds. The feed conversion was improved with increasing levels of energy to a greater extent when higher levels of protein were fed.

The protein-energy studies of Berg et al. (1960) showed that improved growth resulted from the addition of 30 percent fat to 14 percent protein rations. Added fat decreased feed consumption and increased feed efficiency in proportion to the energy supplied.

Thrasher et al. (1960) found that additional protein and/or energy improved the performance of pigs fed corn-soybean meal type rations. Progress reports on later trials by Thrasher et al. (1961) tended to confirm these findings. Feed efficiency was improved 16.1 percent with the additional energy at low protein levels compared with an improvement of 17.1 percent due to the additional energy at the higher protein levels fed in these investigations.

Table 2 gives a summary of the performance of pigs fed varying levels of fat and protein. Data presented show that both rate of growth and feed efficiency were improved by the addition of fat only if the protein level of the ration was adequate. This effect of protein level on the response of pigs to fat is shown more clearly by separating work in which 10 percent fat was added to finishing rations containing a protein level of 11 percent or less as compared with finishing rations containing 15 percent or more protein. In this work fat additions to the lower protein rations slowed growth by 3 percent or

Table 2. Experimental Data on the Effect of Additional Fat in Rations at Different Levels of Protein

Reference	No. pigs per ration	Type of ration	Crude protein %	Added fat %	Daily gain lbs.	Daily feed lbs.	Feed efficiency lbs./cwt.	Percentage change due to fat addition[a]		
								Daily gain %	Daily feed %	Feed efficiency %
Baird(1957)	7	N.R.[b]	11.0	4	1.52	4.89	322			
				8	1.57	4.73	285	3	- 3	11
			15.2	4	1.63	5.12	306			
				8	1.64	4.36	252	1	-15	18
			19.3	4	1.63	5.48	324			
				8	1.61	4.75	283	- 1	-13	13
Sewell(1957)	5	corn-	11-8.7[c]	0	1.56	5.48	351			
		soybean		5	1.38	4.76	345	-12	-13	2
		meal		10	1.37	4.26	311	-12	-22	11
			14-11[c]	0	1.65	5.28	320			
				5	1.87	5.31	284	13	1	11
				10	1.86	4.95	266	13	- 6	17
			17-14[c]	0	1.84	6.07	330			
				5	1.80	5.47	304	- 2	-10	8
				10	1.86	4.87	262	1	-20	21
Abernathy(1958)	5	corn-	14	0	1.71	5.59	326			
		mixed		5	1.89	5.70	302	11	2	7
		protein		10	1.86	5.11	275	9	- 9	16
			18	0	1.72	5.65	328			
				5	1.76	5.19	295	2	- 8	10
				10	1.86	5.23	281	8	- 7	14
		corn-	14	0	1.57	5.15	328			
		mixed		5	1.71	4.55	282	9	-12	14
		protein		10	1.87	5.09	273	19	- 1	17
		+ 0.1%	18	0	1.70	5.57	327			
		lysine		5	1.73	5.09	294	1	- 9	10
				10	1.83	5.09	278	8	- 9	15
Baird(1958)	8	N.R.[b]	15-13-11[c]	0	1.48	5.40	365			
				5	1.43	5.19	363	- 3	- 4	1
				10	1.52	5.27	347	3	- 2	5
			21-19-17[c]	0	1.40	5.18	370			
				5	1.45	5.26	363	4	2	2
				10	1.63	5.12	314	16	- 3	15
Clawson(1958)	12	corn-	12-9[c]	0	1.39	5.55	399			
		mixed		5	1.42	5.01	353	2	-10	12
		protein		10	1.25	4.31	345	-10	-22	14
			15-12[c]	0	1.67	5.64	338			
				5	1.57	5.23	333	- 6	- 7	1
				10	1.79	5.14	287	7	- 9	15
			18-15[c]	0	1.65	5.74	348			
				5	1.64	5.35	326	- 1	- 7	6
				10	1.81	5.30	293	10	- 8	16
Brooks(1959)	6	corn-	14	0	1.30	5.00	384			
		mixed		8	1.44	4.79	332	11	- 4	14
		protein		0	1.31	4 89	374			
				8	1.46	4.67	320	11	- 4	14
Brooks(1959)	6	corn-	14-11-9[c]	0	1.28	5.25	410			
		soybean		6	1.33	4.79	360	4	- 9	12
		meal	16-13-10[c]	0	1.35	5.40	400			
				6	1.49	4.91	330	10	- 9	18
			18-15-12[c]	0	1.45	5.58	385			
				6	1.48	4.80	326	2	-14	15

more and improved feed efficiency by not more than 11 percent while fat addition to the higher protein rations increased growth by 12 percent or more and improved feed efficiency by at least 17 percent (Sewell et al., 1957; Baird et al., 1958; Clawson et al., 1958c and Pond et al., 1960).

Swine Carcass Characteristics as Affected by Protein and Energy Interrelationships in the Ration

Clawson et al. (1958a) found that the addition of fat to corn-soybean meal rations tended to increase backfat thickness. The increase in backfat was less pronounced when lower levels of added fat were fed with higher levels of protein. The area of the loin eye muscle was less with rations containing high calorie-protein ratios, although lower levels of protein also tended to reduce the loin area.

Baird et al. (1958) reported that added tallow did not significantly affect backfat, carcass length or loin area. Ault et al. (1960) reported that pigs fed higher protein levels had similar backfat thickness regardless of tallow level, while the low protein rations with a high tallow level produced a greater backfat thickness.

Abernathy et al. (1958), Perry et al. (1959) and Pond et al. (1960) reported that when fat was used to vary the energy in protein and energy studies the backfat thickness tended to increase with the higher level of added fat.

Pond et al. (1960) stated that the increase in the rate of body weight gain may have caused this increase in fat deposition. Perry et al. (1959) found by using a higher level of protein that the addition of fat to the ration did not result in such a marked increase in backfat

thickness as was obtained with the lower protein high-fat rations.

The data of Thrasher _et al_. (1960) indicated that the addition of 10 percent tallow to low protein rations adversely affected the percentage lean cuts, loin eye area, and backfat thickness, while no such effects were noted with fat added to high protein rations. These measurements were also affected, though not as greatly, by the feeding of low protein rations without tallow.

Berg _et al_. (1960) showed an increase in backfat thickness by the addition of either 15 or 30 percent of fat to the ration at the 14 percent protein level. Fat additions to the ration had less effect on backfat thickness when an 18 percent level of protein was used. They also noted that the loin eye area was smaller when pigs were fed low protein rations.

Brooks and Thomas (1959) fed corn-soybean meal type rations with and without 6 percent lard at three levels of protein, 12, 10 and 9 percent, to finishing pigs. The data showed no differences in backfat due to the treatments. In a second trial they reported the most backfat on pigs given rations with 6 percent lard at the two lowest levels of protein.

Hoefer _et al_. (1960) compared carcasses from pigs fed five types of high fiber rations with a control ration containing corn and soybean meal. These workers reported that corn and cob meal, wheat bran, alfalfa meal and pelleted alfalfa reduced the fat trim by 2 percent and increased the lean cuts approximately 1.5 percent, while oats failed to reduce fat trim or increase lean cuts. In other

observations wheat bran and alfalfa meal were found to decrease backfat thickness.

Bowland *et al*. (1957, 1958) and Beacom (1961) reduced the energy intake of finishing swine in energy-protein relationship studies by adding more oats to the ration. In other work, Bowland (1959) used a chemically inert material with a water holding capacity of 300 percent to replace the oats as an energy depressant. In comparing results with feeding high and low energy rations Bowland reported more backfat and less area of loin with the high energy rations. Differences in backfat and loin area were less with high protein rations. Bowland (1957) found lower carcass grades with high energy rations fed at either a medium or low protein level, while in the later oat ration studies they (Bowland and Berg, 1958) reported that carcass differences were small and pigs tended to grade well regardless of treatment.

Using rations containing either 11.6, 12.8 or 14.1 percent protein Beacom (1961) observed that protein had no effect on either the dressing percentage or backfat thickness, but when the energy level was increased the dressing percentage and backfat thickness were also increased.

Boenker and Tribble (1960) and Noland and Scott (1960) fed three energy levels, a low energy ration with a high fiber content, a medium energy ration and a high energy ration with a high fat content. These rations were fed in combination with three levels of protein. They found that high energy rations with less than 13 percent protein produced greater backfat thickness, whereas no such effect was noted with

higher protein levels. Noland and Scott also reported that significantly longer carcasses with a greater yield of primal cuts were obtained with the 16 and 20 percent protein rations while the energy level had no effect on these measurements.

In summary, it has been shown by several workers that protein and energy interrelationships existed where backfat thickness was used as a criterion in the measurement of carcass quality (Clawson *et al.*, 1958c; Baird, 1957; Perry *et al.*, 1959; Thrasher *et al.*, 1960; Berg *et al.*, 1960; Bowland *et al.*, 1957, 1959; Boenker and Tribble, 1960 and Noland and Scott, 1960).

METHODS AND MATERIALS

Introduction

The studies herein reported were designed to determine (1) the effect of adding animal fat to a growing-finishing swine ration which contained 40 percent oats and (2) the effect of raising the energy level on the protein requirement of growing-finishing swine receiving rations containing 40 percent oats. These studies, which include performance and carcass effects, were conducted in two experiments. Experiments 1 and 2 were as follows:

1. A comparison of fat supplemented fortified corn-soybean meal type rations and fortified corn-oats-soybean meal type rations.
2. A comparison of protein and energy variations in fortified corn-oats-soybean meal rations.

The group feeding trials were conducted beginning in August 1960 and extending to April 1961. A total of thirty lots and one hundred sixty-eight pigs were involved. Pigs were allotted on the basis of ancestry, sex and weight. Each pig was vaccinated for hog cholera and erysipelas. Pigs were treated for internal parasites with piperazine and for external parasites with lindane. Facilities included a barn which was divided into eight-by-nine foot concrete floored pens with outside eight-by-thirteen foot concrete runways. Feed was supplied from self-feeders at the end of the runway and water was supplied by automatic waterers inside the barn.

Each pig was weighed bi-weekly. Feed records were kept throughout the trials.

Individual pigs weighing 200 pounds or more were removed from test at weekly intervals and shipped by truck to be slaughtered at John Morrell and Company, Sioux Falls. Carcasses were then evaluated according to the specifications established by the National Swine Breed Association. Evaluation criteria reported include dressing percentage, average backfat thickness, loin eye area, carcass length and the total lean cuts percentage. The yield or dressing percentage was figured by dividing the chilled carcass (packer style) weight by the final weight before slaughter and multiplying by 100. Backfat thickness measurements were taken on the chilled carcasses at the first rib, last rib and lumbar vertebrae. The average of these three values was then computed and adjusted to 200 pounds using Durham's Correction Factor. This adjustment was made on the basis of the animal's final weight before slaughter. The area of loin eye muscle was measured between the 10th and 11th rib by tracing the outer perimeter with a planimeter. Carcass length was measured from the leading edge of the first rib to the anterior edge of the aitch bone. The percentage of lean cuts was computed by dividing the sum of the weight of the hams, loins, picnics and Boston butts by the weight of the chilled carcasses and multiplying by 100.

The oats used in these studies had an average test weight of 37 pounds per bushel. Crude fiber analysis on the complete mixed ration ranged between 5 and 6 percent indicating that the oats used had a low

fiber content. In order to limit sorting, the oats was ground through a 5/32 inch screen.

The yellow grease used was purchased from John Morrell and Company. This product was manufactured from the remaining low grade offal after the separation of choice white grease. The processing of yellow grease included three hours of cooking in a steam tank at 70 pounds interval pressure, deheading (removal of the foaming portion) and filtration. A stabilizing agent, Tenox, was added to minimize oxidation. This stabilizing agent was made up according to a formula advanced by the American Meat Institute Foundation. The formula contained a mixture of 20 percent butylated hydroxyanisole, 6 percent propyl gallate and 4 percent citric acid in propylene glycol.

The gross energy content was determined on duplicate samples of each ration. The oxygen bomb calorimeter was used for the energy determinations. The crude protein and crude fiber determinations were made on ration samples according to A.O.A.C. methods (1955). The calorie-protein ratio was calculated by dividing the gross calories per gram by the crude protein per gram.

Experiment 1

Three replicates of six lots each were involved in these studies with the first study beginning on August 16, 1960. In the first replicate thirty-six purebred weanling pigs of the Hampshire, Spotted Poland China and Duroc breeds were allotted to the six lots. Each lot contained three barrows and three gilts. The average initial body weight

of the pigs used in this replicate was approximately 44.3 pounds.

The other two replicates were placed on test October 28, 1960. Duroc, Hampshire, Spotted Poland China and crossbred pigs were allotted to each of the replicates. The ratios of barrows to gilts within each of the two replicates were three to two (Rep 2) and two to three (Rep 3). The initial average body weight of pigs in replicates 2 and 3 was 42.3 pounds and 32.8 pounds, respectively.

The ration treatments were arranged according to a 2 x 3 factorial design. A corn-soybean meal type ration and a ration with 40 percent oats replacing corn were used, with three levels of fat added to each of these two rations. Yellow grease was used at 0, 4 or 8 percent of the ration. Ingredient composition, gross energy and the crude protein content of the rations are presented in Table 3.

One pig was removed from the first replicate of the corn-oat-4 percent fat treatment. This pig failed to gain during the first 30 days of the growing period. The maintenance requirement of this animal was calculated by a method described by Brody (1945). The amount of feed required for maintenance was calculated to be 0.76 poundper day. This figure was arrived at by dividing the TDN required per day by the approximate TDN in the ration. The feed required for daily maintenance was multiplied by the number of days on test, and then this figure was subtracted from the total amount of feed consumed by the lot during the growing period.

A pig in replicate 3 of the corn-oat-4 percent fat treatment died of a cardiac infection during the finishing period. In the two weeks

Table 3. Ingredient Composition of Rations Used in Experiment 1

	Corn rations			Corn-oat rations		
Crude protein, %[a]	18.0	16.8	16.7	18.2	18.7	17.9
Yellow grease level, %	0	4	8	0	4	8
Gross Calories/lb.	1785	1832	1915	1788	1861	1935
	%	%	%	%	%	%
Ground yellow corn	76.0	71.0	66.0	40.0	35.0	30.0
Finely ground oats	---	---	---	40.0	40.0	40.0
Soybean meal (44%)	21.3	22.3	23.3	17.3	18.3	19.3
Stabilized yellow grease	---	4.0	8.0	---	4.0	8.0
Limestone	1.0	1.0	1.0	1.0	1.0	1.0
Dicalcium phosphate	1.0	1.0	1.0	1.0	1.0	1.0
Trace mineral salt (0.5% zinc)	0.5	0.5	0.5	0.5	0.5	0.5
B-vitamin mix[b]	0.1	0.1	0.1	0.1	0.1	0.1
Vitamin B_{12}[c]	0.025	0.025	0.025	0.025	0.025	0.025
Vitamin A and D[d]	0.025	0.025	0.025	0.025	0.025	0.025
Antibiotic[e]	0.05	0.05	0.05	0.05	0.05	0.05

[a]After 110 pounds live weight the protein content of the ration was reduced approximately 2% by replacing 5.7% of the soybean meal with corn.

[b]Merck 92, contained: Riboflavin 2,000 mg., D-pantothenic acid 3,680 mg., Niacin 9,000 mg., Choline chloride 10,000 mg., (guaranteed per pound of supplement).

[c]Merck 20, contained 20 mg. Vitamin B_{12} (activity per pound).

[d]Nopco Quadrex "10" contained: Vitamin A, not less than 4,536,000 U.S.P. units per pound; Vitamin D, not less than 567,000 U.S.P. units per pound of supplement (guaranteed).

[e]Aurofac "10" contained 10 gm. chlortetracycline per pound.

prior to death this animal lost all of the weight it had gained during the initial stages of the period. The amount of feed required for maintenance was calculated and subtracted as described in the preceding paragraph.

Experiment 2

On November 18 seventy-two pigs were divided into two groups which were subdivided into six lots of six animals each. Weanling purebred Spotted Poland China, Hampshire, Yorkshire, Duroc and crossbred pigs were allotted so that all lots contained three barrows and three gilts. The average initial body weight of the pigs was 29.7 pounds for one replicate and 36.6 pounds for the other replicate.

The six lots within each replicate were randomly assigned to a 2 x 3 factorial experiment. The main treatment variables were protein and energy. The ingredient composition, gross energy and crude protein of the rations are shown in Table 4. Cerelose, a corn sugar which is composed of dextrose, and yellow grease were used to vary the energy in these rations.

Table 4. Ingredient Composition of Rations Used in Experiment 2

	High protein[a]			Low protein[a]		
Crude protein, %	14.3	14.4	14.4	12.3	12.5	12.5
Energy level	Low	Medium	High	Low	Medium	High
Gross Calories/lb.	1828	1930	2025	1825	1938	2036
	%	%	%	%	%	%
Ground yellow corn	36.1	36.1	36.1	41.8	41.8	41.8
Finely ground oats	40.0	40.0	40.0	40.0	40.0	40.0
Soybean meal (44%)	13.2	13.2	13.2	7.5	7.5	7.5
Stabilized yellow grease	---	4.0	8.0	---	4.0	8.0
Dextrose	8.0	4.0	---	8.0	4.0	---
Limestone	1.0	1.0	1.0	1.0	1.0	1.0
Dicalcium phosphate	1.0	1.0	1.0	1.0	1.0	1.0
Trace mineral salt (0.5% zinc)	0.5	0.5	0.5	0.5	0.5	0.5
B-vitamin mix[b]	0.1	0.1	0.1	0.1	0.1	0.1
Vitamin B_{12}[c]	0.025	0.025	0.025	0.025	0.025	0.025
Vitamin A and D[d]	0.025	0.025	0.025	0.025	0.025	0.025
Antibiotic[e]	0.05	0.05	0.05	0.05	0.05	0.05

[a]After 110 pounds live weight the protein content of the ration was reduced approximately 2% by replacing 5.7% of the soybean meal with corn.

[b]Merck 92, contains: Riboflavin 2,000 mg., D-pantothenic acid 3,680 mg., Niacin 9,000 mg., Choline chloride 10,000 mg. (guaranteed per pound of supplement).

[c]Merck 20, contains 20 mg. Vitamin B_{12} (activity per pound).

[d]Nopco Quadrex "10" contained: Vitamin A, not less than 4,536,000 U.S.P. units per pound; Vitamin D, not less than 567,000 U.S.P. units per pound of supplement (guaranteed).

[e]Aurofac "10" contained 10 gm. chlortetracycline per pound.

RESULTS AND DISCUSSION

Experiments 1 and 2 were conducted in two periods--growing period and finishing period. The growing period is discussed separately before the overall results of the entire growing and finishing period. The average daily gain data were treated statistically by the analysis of variance as described by Snedecor (1956). The results of the carcass evaluation are discussed last. Carcass data treated statistically by the analysis of variance included percentage carcass yield, percentage lean cuts, loin eye area, backfat thickness and carcass length.

Effect of Adding Fat to Corn and Corn-Oat Rations-Experiment 1

Growing period

The performance of pigs during the growing period is reported in Table 5. The effects of corn rations compared with corn-oat rations and the effects of fat additions at 4 or 8 percent are summarized in Table 6.

An average of the three energy levels with each type of ration showed that pigs fed corn rations gained significantly ($P<0.05$) faster than pigs fed corn-oat rations. This amounted to 6 percent faster gain. A comparison of the growth rate of pigs fed corn and corn-oat rations without fat shows no difference in average daily gains. The average daily gains of pigs fed corn rations with fat were increased 0.14 and 0.11 pound with 4 and 8 percent fat additions, respectively. Pigs given corn-oat rations with 4 percent added fat gained 0.06 pound less

Table 5. Performance of Swine Fed Corn or Corn-Oat Rations With Varying Levels of Fat During the Growing Period

	Corn rations			Corn-oat rations		
Yellow grease level, %	0	4	8	0	4	8
Number of pigs						
Rep 1	6	5	6	6	6	6
Rep 2	5	5	5	5	5	5
Rep 3	5	5	5	5	5	5
Total	16	15	16	16	16	16
Av. no. days on test						
Rep 1	44	44	44	44	44	44
Rep 2	42	42	42	42	42	42
Rep 3	53	53	53	53	53	53
Average	46	46	46	46	46	46
Av. wt. at feed change, lb.[a]						
Rep 1	105.3	114.0	107.5	105.2	101.2	109.8
Rep 2	104.8	115.8	114.0	110.2	108.0	108.2
Rep 3	118.4	121.6	122.6	112.2	109.6	114.6
Average	109.2	117.1	114.2	108.9	105.9	110.8
Av. daily gain, lb.						
Rep 1	1.39	1.52	1.44	1.38	1.30	1.48
Rep 2	1.48	1.75	1.70	1.62	1.57	1.57
Rep 3	1.62	1.68	1.69	1.50	1.44	1.54
Average	1.50	1.64	1.61	1.49	1.43	1.53
Av. daily feed/pig, lb.						
Rep 1	3.82	3.67	3.49	3.99	3.43	3.57
Rep 2	4.05	4.40	4.02	4.40	4.10	4.11
Rep 3	4.47	3.91	4.32	4.26	4.00	4.54
Average	4.12	3.98	3.94	4.20	3.82	4.07
Av. feed/lb. of gain, lb.						
Rep 1	2.75	2.48	2.43	2.88	2.65	2.41
Rep 2	2.73	2.51	2.36	2.72	2.62	2.62
Rep 3	2.77	2.34	2.55	2.85	2.77	2.94
Average	2.75	2.44	2.45	2.82	2.68	2.66

[a]Average pounds initial weight of each rep: Rep 1, 44.3; Rep 2, 42.2; and Rep 3, 32.8; average of all reps 40.1.

Table 6. Effects of Ration Type and Fat Level on the Performance of Swine

	Growing period					Growing-finishing period				
	Type ration[a]		Grease level, %[b]			Type ration[a]		Grease level, %[b]		
	Corn	Corn-oat	0	4	8	Corn	Corn-oat	0	4	8
Number of pigs										
Rep 1	17	18	12	11	12	17	18	12	11	12
Rep 2	14	15	10	9	10	14	15	10	9	10
Rep 3	15	15	10	10	10	15	15	10	10	10
Total	46	48	32	30	32	46	48	32	30	32
Av. daily gain, lb.										
Rep 1	1.45	1.39	1.38	1.41	1.46	1.84	1.75	1.78	1.77	1.84
Rep 2	1.64	1.59	1.55	1.66	1.64	1.88	1.79	1.76	1.88	1.87
Rep 3	1.66	1.49	1.56	1.56	1.62	1.88	1.74	1.80	1.80	1.83
Average	1.58[c]	1.48	1.50	1.54	1.57	1.87[c]	1.76	1.78	1.81	1.84
Av. daily feed/pig, lb.										
Rep 1	3.66	3.66	3.90	3.50	3.53	5.56	5.82	6.08	5.60	5.52
Rep 2	4.16	4.20	4.22	4.25	4.06	6.03	6.10	6.33	6.10	5.77
Rep 3	4.23	4.27	4.36	3.96	4.43	5.74	5.96	6.22	5.58	5.75
Average	4.01	4.03	4.16	3.90	4.00	5.78	5.95	6.20	5.72	5.67
Av. feed/lb. of gain, lb.										
Rep 1	2.53	2.65	2.82	2.54	2.42	3.06	3.33	3.41	3.18	3.00
Rep 2	2.53	2.65	2.72	2.56	2.49	3.21	3.41	3.58	3.26	3.08
Rep 3	2.55	2.85	2.81	2.56	2.74	3.05	3.43	3.46	3.12	3.15
Average	2.54	2.72	2.78	2.55	2.56	3.10	3.39	3.48	3.18	3.08

[a]Average of all corn rations compared with the average of all corn-oat rations.
[b]Average of corn and corn-oat rations with each level of fat.
[c]Significant ($P < 0.05$) over corn-oat rations.

per day than those fed corn-oat rations without added fat. Average daily gains with the ration containing 8 percent added fat were 0.03 pound faster than when no fat was used. This suggests that fat additions were more effective in inducing rapid gains with corn rations than with corn-oat rations.

The feed consumption of pigs on corn-oat rations containing no added fat was 0.08 pound per day greater than that of pigs on the no fat corn ration. It appeared that pigs fed the corn-oat ration ate more in order to compensate for the lower TDN content. Studies of Jensen et al. (1959) did not agree; in fact, pigs fed corn-oat rations consumed less feed than those fed corn rations. In their studies the level of oats used was also 40 percent, but the test weight was 32 pounds compared with 37 pounds per bushel for the oats used in these experiments.

In general, feed consumption was reduced with the addition of fat to either the corn or corn-oat ration. Average daily feed consumption of corn rations containing 4 or 8 percent added fat was 0.14 and 0.18 pound, respectively, lower than when no fat was added. Pigs fed corn-oat rations with 4 or 8 percent fat consumed 0.38 and 0.13 pound, respectively, less feed per day. The pigs fed the 4 percent fat corn-oat ration had the lowest feed consumption and the slowest daily gains of all treatments. The corn-oat ration with 8 percent added fat was wasted to a considerable extent by the pigs in replicate 3 of the first experiment. Thus the true feed consumption was less than appears for this replicate in Table 5.

The feed efficiency of pigs fed the corn ration with no added fat was about 3 percent greater than the feed efficiency of pigs fed the corn-oat ration without added fat. The feed required per pound of gain was reduced as the level of energy was increased in both the corn and corn-oat rations. The addition of 4 or 8 percent fat to corn rations reduced the feed required per pound of body weight gain by about one-third of a pound. The addition of fat to corn-oat rations improved feed efficiency but this improvement was about 50 percent less than that noted with the addition of fat to corn rations.

Growing and finishing periods combined

The results of pig performance over the entire growing and finishing period are presented in Table 7. The effects of corn rations compared with corn-oat rations and the effect of fat additions at 4 or 8 percent are summarized in Table 6.

A comparison of the growth rates on all the corn rations and all the corn-oat rations with or without added fat showed significantly ($P < 0.05$) greater gains with pigs fed corn rations. Rate of gain was improved 6 percent with the corn rations.

Although no differences in average daily gain occurred with pigs fed the no fat corn or corn-oat rations during the growing period, slight differences were observed when the finishing period was considered. With these no fat rations an increase of 0.05 pound average daily gain was obtained with the pigs fed the corn ration. Jensen *et al*. (1957), Sewell *et al*. (1957), Wahlstrom (1959) and Seerley (1960) fed corn and

Table 7. Performance of Swine Fed Corn or Corn-Oat Rations With Varying Levels of Fat During the Growing and Finishing Period

	Corn rations			Corn-oat rations		
Yellow grease level, %	0	4	8	0	4	8
Number of pigs						
Rep 1	6	5	6	6	6	6
Rep 2	5	4	5	5	5	5
Rep 3	5	5	5	5	5	5
Total	16	14	16	16	16	16
Av. no. days on test						
Rep 1	92.2	88.0	91.7	94.2	100.5	92.5
Rep 2	96.2	84.2	89.0	92.2	96.0	91.8
Rep 3	94.8	93.4	93.2	102.0	104.8	99.0
Average	94.2	88.4	91.3	96.0	100.4	94.3
Av. final wt., lb.[a]						
Rep 1	213.0	210.8	213.3	208.0	212.7	214.2
Rep 2	210.8	211.0	211.8	206.4	210.8	211.2
Rep 3	207.6	209.4	210.8	211.6	212.0	206.2
Average	210.6	210.4	212.1	208.6	211.9	210.8
Av. daily gain, lb.						
Rep 1	1.83	1.86	1.84	1.74	1.68	1.83
Rep 2	1.75	1.99	1.90	1.78	1.76	1.84
Rep 3	1.84	1.89	1 91	1.75	1.71	1.75
Average	1.81	1.91	1.88	1.76	1.71	1.81
Av. daily feed/pig, lb.						
Rep 1	5.84	5.59	5.51	6.31	5.60	5.54
Rep 2	6.28	6.21	5.60	6.38	5.99	5.94
Rep 3	6.24	5.39	5.59	6.21	5.76	5.91
Average	6.10	5.68	5.56	6.30	5.77	5.78
Av. feed/lb. of gain, lb.						
Rep 1	3.19	3.01	2.99	3.63	3.34	3.02
Rep 2	3.58	3.11	2.94	3.58	3.41	3.23
Rep 3	3.38	2.85	2.93	3.54	3.38	3.37
Average	3.37	2.98	2.96	3.59	3.37	3.20

[a]Average pounds initial weight of each rep: Rep 1, 44.3; Rep 2, 42.2; and Rep 3, 32.8; average of all reps 40.1.

corn-oat rations to growing and finishing pigs. Wahlstrom using oats which exceeded 35 pounds per bushel test weight obtained results similar to those observed in this experiment with 37 pound oats. The other authors reported greater decreases in rate of gain due to the addition of oats to the rations.

Fat addition to corn rations improved average daily gains 5 percent while little or no effect on growth was observed with fat additions to corn-oat rations.

An average of 0.17 pound more feed per day was consumed by pigs fed the corn-oat rations compared with those receiving corn rations. This is the average difference in feed consumption of all pigs fed the corn rations and all pigs fed the corn-oat rations both with and without added fat. Brooks and Thomas (1959) and Hoefer et al. (1960) found that pigs fed high fiber low energy rations consumed more feed per day than those fed low fiber high energy rations. Jensen et al. (1957), Sewell et al. (1957) and Wahlstrom (1959) reported that the consumption of corn rations containing oats was decreased when oat levels of 25 percent or more were fed.

The average daily feed consumption by pigs on corn rations with 4 or 8 percent added fat was 0.42 and 0.54 pound, respectively, less per pig than with the no fat corn rations. The addition of either 4 or 8 percent fat to the corn-oat ration decreased daily feed consumption an average of about one-half pound. The addition of either level of fat appeared to reduce feed consumption about 8.5 percent for both the corn and corn-oat rations.

Pigs fed corn rations without added fat required 0.22 pound less feed per pound of gain than was required with the no fat corn-oat rations.

The feed efficiency of pigs fed corn-oat rations was improved by 0.22 and 0.39 pound with fat at 4 and 8 percent levels, respectively, as compared with the ration having no added fat. Four and 8 percent fat additions to the corn rations increased feed efficiency by 0.39 and 0.41 pound, respectively. There was a lack of improvement in feed efficiency with corn rations from the 4 percent fat level to the 8 percent fat level. This may be due to the exceptional performance of pigs in lots receiving the corn ration containing 4 percent fat.

The calorie content of the corn and corn-oat rations was similar with each of the energy levels fed. However, the fiber content of the corn ration was only 2.7 percent while the corn-oat rations contained about 6.2 percent fiber. It required about the same amount of feed to produce a pound of gain with the no fat corn ration as with the corn-oat ration to which 4 percent fat had been added. The addition of 8 percent fat to the corn-oat ration improved feed efficiency 5 percent over the no fat corn ration. This agrees with the work of Becker (1960) who showed that the metabolizable energy content of corn and corn-oat rations could be made equal with the addition of fat to the corn-oat rations at the rate of 1 percent fat to 10 percent oats.

Carcass evaluation

The results of the carcass evaluations are given in Table 8. These data show that the percentage yield from live to dressed chilled weight was 1.16 percent greater for pigs fed all corn rations including

Table 8. Carcass Data for Swine Fed Corn or Corn-Oat Rations With Varying Levels of Fat

	Corn rations			Corn-oat rations			Corn[a]	Corn-oat[a]	Corn and corn-oat[b]		
Yellow grease level, %	0	4	8	0	4	8			0	4	8
Av. final weight, lb.											
Rep 1	213.0	210.8	213.3	208.0	212.7	214.2	212.4	211.6	210.5	211.8	213.8
Rep 2 and 3	207.0	211.8	212.0	209.4	213.0	207.8	210.3	210.1	208.2	212.4	209.9
Average	210.3	211.3	212.7	208.6	212.8	211.0	211.4	210.8	209.4	212.0	211.8
Av. carcass yield, %											
Rep 1	67.37	69.45	70.09	69.09	69.35	68.16	68.97	68.87	68.23	69.40	69.12
Rep 2 and 3	71.21	70.77	69.95	68.58	69.95	68.43	70.64	68.99	69.90	70.36	69.19
Average	69.09	70.14	70.05	68.84	69.64	68.29	69.76	68.92	68.96	69.89	69.17
Av. lean cuts, %											
Rep 1	51.80	51.54	51.03	52.00	51.64	50.48	51.46	51.37	51.90	51.59	51.26
Rep 2 and 3	51.22	50.13	49.46	51.30	50.58	50.68	50.27	50.85	51.26	50.36	50.07
Average	51.54	50.84	50.32	51.69	51.16	50.58	50.90	51.14	51.62	51.00	50.45
Av. loin eye area, sq. in.											
Rep 1	4.38	4.50	4.09	4.11	4.20	4.15	4.32	4.15	4.24	4.35	4.12
Rep 2 and 3	4.11	3.85	4.04	3.72	4.04	3.97	4.00	3.91	3.92	3.94	4.00
Average	4.26	4.18	4.07	3.93	4.13	4.06	4.17	4.04	4.10	4.16	4.06
Av. backfat, in.											
Rep 1	1.56	1.58	1.64	1.61	1.42	1.55	1.59	1.53	1.58	1.50	1.59
Rep 2 and 3	1.38	1.50	1.45	1.45	1.45	1.52	1.44	1.47	1.41	1.47	1.49
Average	1.46	1.54	1.54	1.52	1.44	1.54	1.51	1.50	1.49	1.48	1.54
Av. carcass length, in.											
Rep 1	29.6	29.6	29.6	29.5	29.8	30.2	29.6	29.8	29.6	29.7	29.9
Rep 2 and 3	28.5	28.7	28.3	28.7	29.0	28.2	28.5	28.6	28.6	28.8	28.2
Average	29.0	29.1	29.0	29.1	29.5	29.0	29.0	29.2	29.0	29.3	29.0

[a]Average of all corn rations compared with the average of all corn-oat rations.
[b]Average of corn and corn-oat rations with each level of fat.

the three levels of added fat when compared with those pigs given similar corn-oat rations. The addition of fat to either of the two rations had little or no effect on the carcass yield.

The percentage of lean cuts was reduced as the level of fat increased. The lean cuts were 0.70 and 1.22 percent lower with the corn rations containing added fat at levels of 4 and 8 percent, respectively, when compared with the no fat corn rations. The addition of 4 percent fat to the corn-oat ration decreased lean cuts by 0.53 percent while 8 percent added fat decreased lean cuts by 1.11 percent. Hillier (1950) and Barrick _et al_. (1953) found that added fat had little or no effect on the yield of lean cuts.

The loin eye area, backfat thickness and carcass length appeared to be unaffected by any of the rations tested. Hochstetler _et al_. (1958) found no significant differences in backfat or lean cuts when corn and corn-oat rations were compared.

Effect of Varying Protein and Energy Levels in Corn-Oat Rations-Experiment 2

Growing period

The performance of pigs during the growing period is presented in Table 9. A summary of data on protein and energy effects is presented in Table 10.

The feeding of high protein rations to growing pigs resulted in significantly ($P < 0.05$) faster growth than was obtained with low protein rations. These differences amounted to 11 percent more average daily gain when rations contained 14.4 percent protein compared with 12.4

Table 9. Performance of Swine Fed Corn-Oat Rations With Varying Protein and Energy Levels During the Growing Period[a]

	Low protein			High protein		
Energy level	Low	Medium	High	Low	Medium	High
Number of pigs[b]	12	12	12	12	12	12
Av. wt. at feed change, lb.[c]						
Rep 1	105.7	105.7	101.0	108.2	109.2	115.3
Rep 2	114.2	106.0	110.0	121.3	122.3	117.7
Average	109.9	105.8	105.5	114.8	115.8	116.5
Av. daily gain, lb.						
Rep 1	1.50	1.50	1.40	1.55	1.58	1.71
Rep 2	1.40	1.27	1.34	1.53	1.54	1.47
Average	1.45	1.37	1.36	1.54	1.56	1.57
Av. daily feed/pig, lb.						
Rep 1	4.50	4.67	4.12	4.66	4.56	4.19
Rep 2	4.32	3.92	3.94	4.39	4.26	4.00
Average	4.40	4.25	4.02	4.51	4.39	4.08
Av. daily gross Cal./pig	8030	8236	8184	8245	8472	8262
Av. daily protein/pig, lb.	0.54	0.53	0.50	0.64	0.63	0.59
Av. feed/lb. of gain, lb.						
Rep 1	3.00	3.11	2.95	3.00	2.89	2.45
Rep 2	3.07	3.09	2.94	2.87	2.76	2.72
Average	3.04	3.10	2.94	2.93	2.82	2.60
Av. gross Cal./lb. of gain	5548	6008	5985	5356	5442	5265
Av. protein/lb. of gain, lb.	0.37	0.39	0.37	0.42	0.40	0.37
Calorie/protein ratio	32.7	34.0	35.8	28.2	29.7	30.8

[a]Av. no. days on test: Rep 1, 46; Rep 2, 60.

[b]Six pigs per rep.

[c]Av. initial wt., lb.: Rep 1, 36.7; Rep 2, 29.8; Av., 33.2.

Table 10. Effects of Protein Level and Energy Level on the Performance of Swine Fed Corn-Oat Rations

	Protein level[a]		Energy level[b]		
	Low	High	Low	Medium	High
No. of lots/rep[c]	3	3	2	2	2
Growing Period					
Av. daily gain, lb.					
Rep 1	1.47	1.61	1.52	1.54	1.56
Rep 2	1.33	1.51	1.46	1.40	1.40
Average	1.39	1.56[d]	1.50	1.47	1.47
Av. daily feed/pig, lb.					
Rep 1	4.43	4.47	4.58	4.52	4.16
Rep 2	4.06	4.22	4.36	4.09	3.97
Average	4.22	4.33	4.46	4.32	4.05
Av. daily gross Cal./pig	8150	8326	8137	8359	8223
Av. daily protein/pig, lb.	0.52	0.62	0.59	0.58	0.54
Av. feed/lb. gain, lb.					
Rep 1	3.02	2.78	3.00	3.00	2.70
Rep 2	3.03	2.78	2.97	2.92	2.83
Average	3.03	2.78	2.98	2.96	2.77
Av. gross Cal./lb. gain	5847	5354	5452	5725	5625
Av. protein/lb. gain, lb.	0.38	0.40	0.40	0.40	0.37
Growing-Finishing Period					
Av. daily gain, lb.					
Rep 1	1.65	1.81	1.75	1.71	1.74
Rep 2	1.55	1.65	1.62	1.58	1.60
Average	1.61	1.73[d]	1.68	1.66	1.68
Av. daily feed/pig, lb.					
Rep 1	5.87	5.96	6.21	5.95	5.58
Rep 2	5.41	5.49	5.80	5.40	5.16
Average	5.63	5.71	6.00	5.66	5.36
Av. daily gross Cal./pig	10543	10748	10632	10668	10636
Av. daily protein/pig, lb.	0.63	0.74	0.72	0.68	0.64
Av. feed/lb. gain, lb.					
Rep 1	3.54	3.29	3.54	3.48	3.22
Rep 2	3.48	3.33	3.59	3.42	3.21
Average	3.52	3.31	3.57	3.45	3.22
Av. gross Cal./lb. gain	6593	6216	6331	6503	6379
Av. protein/lb. gain, lb.	0.39	0.43	0.43	0.41	0.38

[a]Average of all energy levels at each protein level.
[b]Average of both protein levels at each energy level.
[c]Six pigs per rep.
[d]Significant ($P<0.05$) over the low protein rations.

percent protein.

Increasing the energy in low protein rations resulted in slower average daily gains of 0.08 pound and 0.09 pound for the medium and high energy rations, respectively, when compared with the low energy ration. In contrast, pigs fed the high protein rations gained slightly faster as the energy level was increased. In replicate 2 the initial body weight of pigs was about 7 pounds less than that of pigs in replicate 1. These smaller pigs gained 0.24 pound per day slower on the high protein-high energy ration than the pigs in replicate 1. In contrast, there were no differences in the growth rate of the pigs in either replicate 1 or replicate 2 when they were fed high protein-low energy rations. This suggested that the smaller pigs may not have had adequate protein even at the higher level when high energy rations were fed. Sewell (1957), Baird (1958), Noland and Scott (1960) and Boenker and Tribble (1960) observed faster growth with high energy rations only when higher levels of protein were used. The protein levels used by these workers during the growing period varied from 11 to 15 percent. Improved growth with the addition of fat was obtained when protein levels were increased 3 or 4 percent.

When the feed consumption of the three energy levels was averaged it was found that pigs consumed 0.11 pound more per day of the high protein rations when compared with feed consumption on the low protein rations. Therefore, the pigs fed high protein rations consumed about 176 more Calories per day. Noland and Scott (1960) and Beacom (1961) observed increased daily feed consumption when high protein

rations were compared with low protein rations. However, Bowland and Berg (1958) reported a decrease in the daily feed consumption of higher protein rations.

Lower feed consumption resulted at both protein levels when the energy level was increased. However, total daily energy intake was increased only from the low to the medium energy level. This increase was 222 Calories per day. A lower daily feed consumption with a subsequent increased energy intake also has been observed by Boenker and Tribble (1960) and Pond <u>et al</u>. (1960), but these workers observed such effects only with higher protein rations.

Feed efficiency comparisons between an average of all high protein rations and an average of all low protein rations indicated that the high protein ration was superior. An average of about 8 percent less feed was required for the gains of those pigs on high protein rations.

The feeding of the low protein level with medium and high energy rations resulted in reduced energy utilization. Pigs fed the medium and high energy rations required 460 and 437 more Calories, respectively, per pound of gain than pigs given the low energy rations. Pigs receiving the high protein rations were able to maintain efficient energy utilization as the energy level of the ration was increased.

A comparison of the various energy levels within each of the protein levels showed that there were no differences in the protein required per pound of gain on the low protein rations, while with the high protein rations protein efficiency improved with the high energy rations.

The protein efficiency on the high protein-high energy ration was similar to that of the low protein-low energy ration.

In summary, it may be stated that efficient protein and energy utilization appear to be directly related. Two other observations support this statement. First, pigs given the high protein-low energy ration required 14 percent more protein per pound of gain than pigs fed the high protein-high energy ration. Secondly, about 8 percent more calories per pound of gain were required with the low protein-high energy ration than were used with the low protein-low energy ration.

Growing and finishing period combined

The results of pig performance over the entire growing and finishing period are presented in Table 11. The overall effects of protein level and energy level are presented in Table 10.

The average daily gains of pigs fed high protein rations were significantly ($P < 0.05$) greater than the gains of pigs on low protein rations. These pigs gained 7.4 percent faster than those fed low protein rations. Pigs fed high protein-low energy rations gained only 3 percent faster than those fed low protein-low energy rations. Greater differences in average daily gains of pigs on high and low protein rations occurred when the energy levels were increased. The average daily gain of pigs fed high energy rations was 13 percent greater on the high protein than on the low protein level. This suggests that these significant increases in average daily gains were due largely to the higher energy levels. A number of workers have reported slower growth with low protein-high energy rations as compared

Table 11. Performance of Swine Fed Corn-Oat Rations With Varying Protein and Energy Levels During the Growing and Finishing Period

	Low protein			High protein		
Energy level	Low	Medium	High	Low	Medium	High
Number of pigs[a]	12	12	12	12	12	12
Av. no. days on test						
Rep 1	92.2	99.8	105.5	92.7	92.7	88.0
Rep 2	107.0	110.2	109.0	107.0	102.0	102.0
Average	101.6	105.0	107.2	107.3	97.3	95.0
Av. final wt., lb.[b]						
Rep 1	201.8	202.5	203.8	202.2	200.0	204.3
Rep 2	200.8	195.7	199.0	204.5	199.0	199.2
Average	201.3	199.1	201.4	203.3	199.5	201.8
Av. daily gain, lb.						
Rep 1	1.72	1.66	1.58	1.78	1.76	1.90
Rep 2	1.60	1.50	1.55	1.63	1.66	1.66
Average	1.65	1.60	1.57	1.70	1.71	1.78
Av. daily feed/pig, lb.						
Rep 1	6.17	5.96	5.48	6.25	5.94	5.69
Rep 2	5.82	5.24	5.17	5.78	5.56	5.14
Average	5.99	5.58	5.32	6.00	5.74	5.40
Av. daily gross Cal./pig	10556	10525	10549	10709	10812	10723
Av. daily protein/pig, lb.	0.67	0.62	0.58	0.78	0.75	0.70
Av. feed/lb. of gain, lb.						
Rep 1	3.59	3.58	3.46	3.50	3.37	2.99
Rep 2	3.64	3.48	3.33	3.54	3.35	3.09
Average	3.62	3.54	3.39	3.52	3.36	3.04
Av. gross Cal./lb. of gain	6379	6677	6723	6282	6329	6036
Av. protein/lb. of gain, lb.	0.40	0.39	0.37	0.46	0.44	0.40
Calorie/protein ratio	36.2	40.2	42.6	32.0	34.0	36.0

[a]Six pigs per rep.
[b]Av. initial wt., lb.: Rep 1, 36.7; Rep 2, 29.8; Av., 33.2.

to low protein-low energy rations (Sewell, 1957; Baird, 1958; Thrasher, 1960; Boenker and Tribble, 1960 and Pond et al., 1960).

As the level of energy was increased in either the low or high protein rations the average daily feed consumption was reduced. An average of 5.7 and 10.7 percent less feed was consumed by pigs fed the medium and high energy rations, respectively, when compared with the low energy rations. Although daily feed consumption decreased as the energy level increased, the energy intake did not vary more than 1 percent from the low energy ration. The primary factor in the voluntary feed intake of growing and finishing pigs appeared to be the need for energy, while the dietary protein exerted little or no influence on feed intake. The slightly higher feed or energy consumption of the high protein rations may have been due at least in part to the faster growth of these animals.

Six percent less feed was required per pound of gain with pigs fed high protein rations when all energy levels were averaged. However, the protein required per pound of gain was 10 percent greater when pigs were fed high protein rations compared with those receiving low protein rations. As the energy level was increased in either the high or low protein rations, less feed was required per pound of gain. Pond et al. (1960) found that average TDN and protein per pound of gain were decreased with 10 percent fat at both 10 and 18 percent protein levels. Pigs fed the high energy ration with the high protein level utilized feed 11 percent more efficiently than those fed the low protein level. This improvement in feed efficiency was 687 Calories per pound of gain.

The protein required per pound of gain decreased as the energy level increased at both protein levels tested. This was not true when only the growing period was considered. It will be recalled that at the low protein level the protein efficiency was not improved with increased energy. In other words, as the energy level is increased the protein level also must be increased if the full benefit of higher levels of energy is to be achieved.

The most effective calorie-protein ratio was found to be between 30:1 and 33:1 (Calories per gram of protein) with each of the protein levels tested during the growing period. Based on rate of gain and feed efficiency during the finishing period the most effective calorie-protein ratio was 36:1. These calorie-protein ratios were more effective in promoting faster growth and increased energy efficiency with pigs fed high protein rations. Table 10 shows that pigs gained an average of 1.78 pounds per day on the high protein-high energy ration with a calorie-protein ratio of 36:1 while on the low protein-low energy ration pigs gained 1.65 pounds per day. The energy efficiency for pigs fed the high protein rations was 6216 Calories per pound of gain while on the low protein rations 6593 Calories were required. These improved results with the high protein-high energy ration suggest the possibility that either better protein quality, increased energy, or both, were beneficial. Clawson _et al_. (1958a, b) reported that pigs fed calorie-protein ratios ranging from 21 to 29 were not influenced in rate and efficiency of gain while those fed rations with ratios ranging from 26 to 38 showed slight decreases in

rate and efficiency of gains with higher ratios.

The possible effects that the fat and sugar additions had on the digestibility and availability of the other ration components deserves discussion. Skipitaris et al. (1957) reported that the apparent digestibility of protein may be decreased by added sugar, while Clawson et al. (1958a) reported that added fat increased digestibility of protein. If the observations of these workers held for the studies reported in this thesis the high energy (high fat) rations would have more available protein. This may account for the decreased amount of protein required per pound of gain with these rations. However, it would not account for the reductions in the rate of gain that were observed with the pigs fed low protein-high energy (fat) rations.

Carcass evaluations

Table 12 gives carcass data for the second experiment. The percentage yield from live to chilled dressed carcass weight was the greatest for the pigs fed the high energy-low protein rations. Pigs fed the high protein-high energy ration had the lowest carcass yield. This lower carcass yield may have been due to the fact that data on two carcasses from this high protein-high energy lot were trimmed before chilled carcass weights were taken.

An average of 50.74 percent lean cuts was obtained from pigs fed the high protein rations while 49.56 percent lean cuts was obtained from pigs fed the low protein rations. This difference of 1.2 percent was significant (P 0.05). These results are in agreement with Noland and Scott (1960) and Thrasher (1960) who also observed a higher percentage

Table 12. Carcass Data for Swine Fed Corn-Oat Rations With Varying Protein and Energy Levels

	Low protein			High protein			Protein level		Energy level		
	Low	Medium	High	Low	Medium	High	Low	High	Low	Medium	High
Av. final weight, lb.											
Rep 1	201.8	202.0	204.0	202.0	200.0	204.3	202.6	202.1	201.9	201.0	204.2
Rep 2	200.8	195.7	199.0	204.5	199.0	199.2	198.5	200.9	202.6	197.4	199.1
Average	201.3	199.1	201.4	203.3	199.5	201.8	200.6	201.5	202.3	199.3	201.6
Av. carcass yield, %											
Rep 1	69.19	70.88	71.37	69.79	70.85	70.19	70.48	70.27	69.48	70.86	70.78
Rep 2	69.73	70.49	71.50	69.39	70.63	67.99	70.57	69.34	69.56	70.56	69.75
Average	69.46	70.68	71.43	69.58	70.74	69.09	70.51	69.80	69.52	70.71	70.26
Av. lean cuts, %											
Rep 1	50.05	49.28	48.62	51.20	50.39	48.75	49.31	50.11	50.62	49.83	48.68
Rep 2	51.97	49.81	48.65	51.38	51.75	51.04	49.81	51.41	51.17	50.78	49.73
Average	50.51	49.54	48.63	51.29	51.07	49.79	49.56	50.74[a]	50.90[b]	50.30[b]	49.19
Av. loin eye area, sq. in.											
Rep 1	3.88	3.84	4.08	4.02	4.17	3.89	3.94	4.03	3.95	4.01	3.98
Rep 2	4.03	3.42	3.74	4.35	4.24	4.41	3.73	4.35	4.19	3.83	4.08
Average	3.96	3.63	3.91	4.18	4.21	4.15	3.83	4.18[c]	4.07	3.92	4.03
Av. backfat, in.											
Rep 1	1.58	1.71	1.76	1.57	1.62	1.64	1.68	1.61	1.58	1.66	1.70
Rep 2	1.56	1.67	1.77	1.56	1.57	1.52	1.67	1.55	1.56	1.62	1.64
Average	1.57	1.69	1.76	1.57	1.59	1.58	1.67[c]	1.58	1.57	1.64[b]	1.67[b]
Av. carcass length, in.											
Rep 1	28.7	28.2	28.5	28.5	28.4	28.4	28.5	28.4	28.6	28.3	28.4
Rep 2	29.2	29.4	29.0	28.8	28.6	28.2	29.2	28.5	29.0	29.0	28.6
Average	29.0	28.8	28.8	28.6	28.5	28.3	28.9	28.5	28.8	28.6	28.6

[a]Significant $(P < 0.05)$ over the other protein level.
[b]Significant $(P < 0.05)$ over the other energy level.
[c]Significant $(P < 0.01)$ over the other protein level.

lean cuts with higher protein levels.

The percentage lean cuts was significantly ($P<0.05$) greater in pigs fed low and medium energy rations than in pigs fed high energy rations. Pigs fed the low and medium energy rations had 1.71 and 1.11 percent more lean cuts, respectively, than were obtained from pigs fed the high energy ration. Beacom (1961) reported a similar increase in the percentage of lean cuts when the energy level of the ration was decreased.

Pigs fed high protein rations had significantly ($P<0.01$) larger loin eye areas. Loin eye areas were 0.35 square inch, or 9 percent, greater with the high protein rations. The energy level had practically no effect on loin eye area. A number of other workers have also noted that larger loin eye areas were produced by pigs fed high protein levels (Wahlstrom, 1954; Clawson, 1958; Bowland, 1959; Thrasher, 1960 and Beacom, 1961).

Backfat thickness was 0.09 inch greater with the low protein ration. This difference was significant ($P<0.01$). Higher energy levels also increased backfat thickness significantly ($P<0.05$). The backfat thickness was increased from the low to the medium energy levels by 0.07 inch, while from the medium to the high level of energy, backfat thickness was increased 0.03 inch.

The protein-energy interaction approached significance. The energy level did not appreciably affect backfat thickness when high protein rations were used. In contrast, backfat thickness was increased as the level of energy was increased with low protein rations. These

increases amounted to 0.12 and 0.19 inch with the medium and high levels of energy when compared with the low energy level. Average backfat thicknesses were the same with pigs fed low energy rations at both protein levels. Boenker and Tribble (1960) and Thrasher (1960) also observed increased backfat thickness with low protein rations, while with high protein levels backfat thickness was unchanged.

There were practically no differences in the carcass length of pigs fed any of the rations.

Two observations are apparent. First, a greater protein efficiency occurred with the low protein and high energy rations, and, secondly, poorer energy efficiency was obtained with pigs fed low protein high energy rations. This may be accounted for in the muscle development and fat deposition during the finishing period. High calorie-protein ratios and added fat were reported by Clawson et al. (1958) to increase carcass fatness.

SUMMARY

One hundred sixty-eight weanling pigs were used in two experiments conducted to study the effects of dietary energy, type of ration and quantity of protein on performance and carcass characteristics. The first experiment was initiated to determine the effect of adding animal fats to two types of rations. These rations were a fortified corn-soybean meal ration and a fortified corn-40 percent oat-soybean meal ration. Four and 8 percent yellow grease were added to each basic type ration. The second experiment was conducted to determine the effect of varying the protein and energy levels in corn-oat rations.

In experiment 1 pigs fed corn rations gained significantly ($P<0.05$) faster than pigs fed corn-oat rations. Feed efficiency was also improved when the corn rations were fed. Gains were improved slightly when fat was added to corn rations, but no appreciable effect was observed in gains when fat was added to corn-oat rations. The addition of fat to either the corn or the corn-oat rations decreased feed consumption and improved feed efficiency.

Carcass evaluations showed that there were no significant differences in carcass yield, percentage lean cuts, backfat thickness, loin eye area or carcass length. There was some indication that the percentage lean cuts was reduced by increasing levels of added fat.

In experiment 2 the average daily gain of pigs fed the high protein ration was significantly ($P<0.05$) faster than that of pigs fed the low protein ration. As the energy level was increased in high protein rations pigs gained slightly faster. In contrast, pigs grew

at a slightly slower rate when additional energy was added to low protein rations.

Average daily feed consumption was reduced as the energy level was increased in both the high and low protein rations. Energy intake did not vary appreciably with the three levels of energy used at each protein level. Pigs fed the high protein rations consumed slightly more energy than those fed low protein rations.

Feed efficiency was improved linearly as the level of energy was increased with both levels of protein. This improvement in feed efficiency was greater for pigs fed high protein rations when compared with those receiving low protein rations. Energy efficiency was decreased as the level of energy was increased in low protein rations. Energy efficiency was increased slightly with pigs fed the high protein rations when the low and high level of energy was compared.

The carcass evaluations indicated that pigs fed high protein rations produced carcasses with a significantly ($P < 0.05$) higher percentage of lean cuts, significantly ($P < 0.01$) less backfat thickness and significantly ($P < 0.01$) more loin eye area. Additional energy in the rations resulted in significantly ($P < 0.05$) more backfat thickness and a significantly ($P < 0.05$) lower percentage of lean cuts. The protein-energy interaction approached significance ($P < 0.05$) with the backfat measurements. This indicated that higher energy levels increased backfat thickness when pigs were fed low protein rations, but backfat thickness was not appreciably affected by increased energy levels in high protein rations.

There was a trend for the carcass yield to increase slightly but not significantly as the energy level was increased except for the high protein-high energy ration.

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