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The effect of form and level of fat and supplemental lysine on the performance of weanling pigs

John W. Tanner

To the Graduate Council:

I am submitting herewith a thesis written by John W. Tanner entitled "The effect of form and level of fat and supplemental lysine on the performance of weanling pigs." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

J. P. Hitchcock, Major Professor

We have read this thesis and recommend its acceptance:

J. B. McLaren, Frank B. Masincupp

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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THE EFFECT OF FORM AND LEVEL OF FAT AND SUPPLEMENTAL LYSINE ON THE PERFORMANCE OF WEANLING PIGS

A Thesis

Presented for the

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Degree

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John W. Tanner

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ABSTRACT

Two experiments were conducted to evaluate the effect of lysine and form and level of fat on weanling pig performance. In experiment 1, 56 weanling pigs were housed individually and eight pigs were fed each of the seven different diets, a basal and six others containing 1, 2 or 3% added liquid or added dry fat. The pigs were fed twice daily an ad libitum level for two weeks. Pigs fed the dry fat diets had lower average daily gains during the experiment, than did pigs fed liquid fat diets ($p < .05$). Initial weight affected feed efficiency ($p < .05$) and feed consumption. Metabolizable energy consumption was not affected by diet ($p > .05$). Lysine consumption per day was affected by fat source ($p < .05$).

In experiment 2, 54 weanling pigs were housed individually and each pig was fed one of the following diets designed in a 3 X 3 factorial arrangement utilizing 3 levels of lysine (.80, .95 and 1.10) and 3 levels of fat (0, 5% dry or 5% liquid). The pigs were fed their respective diets ad libitum twice daily for three weeks. Pigs fed the control diets had a higher average daily gain (ADG) during the second week ($p < .05$) than pigs fed either the dry fat or liquid fat diets. Initial weight had an effect on pig gain ($p < .05$). An increase in lysine level from .80 to .95% in diets with no added fat decreased ADG during the second and third week and overall compared to that of week 1 but increased ADG from .95 to 1.10% ($p < .05$). For pigs fed the dry fat diets, ADG during week 2,3 and overall increased up to the .95% level of added lysine, and then it decreased ($p < .05$). Pigs fed the liquid fat diets tended to have ($p = .05$) a linear decrease in ADG during week 2,3 and overall, as lysine level increased from .80 to .95 to 1.10%. Feed efficiency was improved for pigs fed the control diets compared to pigs fed either of the fat diets during week 2 ($p < .05$). Animals fed the control diets during the third week consumed less feed ($p < .05$). There was no diet effect on lysine consumption during week 1, 2 or 3 ($p > .05$), lysine consumption per kilogram of gain during week 1, metabolizable energy (ME) consumption during week 1, 2 or 3 or ME consumption per gram of gain during all three weeks. Based on these experiments, feeding a level of added fat of 2 or 3%, seems to be the optimum added level to improve performance of weanling pigs. If fat is fed at higher levels than this then the essential amino acids need to be added to the diet in order to compensate for the lack of available nutrients. Key Words: Weanling pigs, Lysine, Metabolizable energy, Fat, Performance.

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CHAPTER 1

INTRODUCTION

The use of added fat in the diets of young, growing pigs has been studied by numerous researchers. One of the uses of added fat in the pigs diet has been to reduce the amount of dust present in a confinement unit which comes from the feed itself and from other sources (Gore et al., 1986). Fat has also been added to the diet of a young pig in order to increase the palatability of the diet. This in turn would hopefully cause the pig to consume more feed and increase gain, thus improving his overall performance.

As the level of added fat in the diet was increased, the feed intake of the pigs decreased (Allee, 1985). Others have shown that increasing the level of added fat in the diet caused an increase in average daily gain and an improvement in feed efficiency of the pigs (Keaschall et al., 1981; Leibbrandt et al., 1975).

When fat is fed at increasing levels in the diet there is a point at which the pigs will begin to eat less feed either because the amount of fat in that diet is too high, or because they are consuming too much energy and lack the ability to store and use it. Added fat in the diet provides a source of highly concentrated energy for the pig since fat has 2.25 times the energy of either protein or carbohydrates. The concentration of energy in the fat and the resulting reduction in feed intake of the pigs may cause the pigs to gain less due to a reduction in intake of other nutrients needed by the pigs (Allee, 1985).

In order to offset a reduction in feed intake of pigs fed diets with increasing levels of added fat, various nutrients have been added to their diets in addition to the fat. It has been shown that with increasing levels of lysine in the diet, the pigs performance in terms of average daily gain and feed efficiency has improved (Maynor and Seerley, 1986). Lysine is one of the most limiting amino acids and is added to a diet with added fat to offset any reduction in the utilization of lysine, already present in the diet of the pig. Some of the other limiting amino acids such as tryptophan and threonine have also been added to diets containing fat. Some experiments have been performed with various levels of protein fed in high energy diets to determine the effects that various protein levels would have on the performance of the pigs (Campbell, 1977).

Therefore, this study's objectives were (1) to determine the effect of source of fat on the performance of weanling pigs, (2) to determine the effect of increasing added levels and source of fat on the performance of the pigs and (3) to determine if an increase in the level of lysine in an isonitrogenous, isocaloric diet affected the pig's performance.

CHAPTER 2

LITERATURE REVIEW

I. Addition of Amino Acids to Low Protein Diets

There have been several experiments performed in the past in which young, growing pigs were fed diets low in protein. These diets were supplemented with individual amino acids in order to bring the percentage crude protein (% CP) of the diet up to the National Research Council (NRC) (NRC, 1979) recommended levels of the young pig. The standard level of crude protein fed in these diets among several experiments was 12% CP. This level was tested against a control of at least 18% CP. Borg et al. (1985a), reported that the addition of L-tryptophan to the diet, resulted in a linear increase in overall performance of the pig. Daily gains increased up to 67% and feed consumption 50% when the low protein diet was supplemented with from .05 to .1% L-tryptophan. These results were similar to the animal's performance when they were fed the 18% CP diet. Tryptophan was added to this diet because it was determined from earlier experiments that it was a limiting amino acid (Borg et al., 1985a).

In another experiment, L-threonine was added to a 12% CP amino acid diet adequate in all amino acids except threonine to determine the threonine requirement of weanling pigs (Borg et al., 1985b). With increased levels of threonine in the basal diet, the average daily gain of the pigs was improved, but they were not different from the gain of pigs fed 18% CP diets. The dietary threonine requirement, as determined in this experiment was .63% threonine, for the 10 kg pig (Borg et al., 1985b).

Borg et al. (1985c), performed a third experiment, in which they tested the effect of protein level (12,15,18 and 21%) in corn-sunflower meal diets containing all essential amino acids in excess of (NRC) recommendations. They wanted to determine the effect of glutamic acid supplementation to a low protein (12%) diet as a non-essential amino acid nitrogen source. Feed intake and average daily gain did not differ among pigs fed the 12, 15, 18 or 21% protein corn-sunflower meal diets or the 18% corn-soybean meal diet; however, with the addition of glutamic acid to the corn-sunflower meal diets, feed consumption and rate of gain were significantly reduced (Borg et al., 1985c).

In a further study with lysine-fortified, amino acid supplemented low protein diets it was indicated that added tryptophan did not improve performance of growing pigs (Russell et al., 1981). When tryptophan was added in combination with threonine there was an improvement in average daily gain and feed efficiency of the pigs. The addition of methionine to the diet improved daily gain, but not feed efficiency (Russell et al., 1981). Feeding of either tryptophan or threonine alone to a lysine-fortified, low-protein diet did not affect weight gain or feed efficiency (Wahlstrom et al., 1985). However, when fed in combination, weight gain and feed efficiency were both improved and were equal to that of pigs fed a 16% crude protein diet. The addition of isoleucine and methionine to the low-protein diet with tryptophan and threonine did not result in any further improvement in animal performance (Wahlstrom et al., 1985).

II. Effect of Various Levels of Lysine on Pig Performance

With the addition of increasing levels of lysine to the diet of growing pigs, there is an improvement in average daily gain, feed consumption and feed efficiency. Rosell and Zimmerman (1984) found that feeding dietary lysine levels of 1.15% (.1% added lysine) and 1.20% (.15% added lysine) maximized feed efficiency and resulted in the lowest plasma urea N values. With the addition of threonine to the diets, performance of the pigs was not affected, but plasma urea N was increased and plasma lysine concentrations were decreased. Plasma urea N (nitrogen) was also increased by the addition of arginine. Neither added arginine nor threonine caused any adverse effects on the pigs performance (Rosell and Zimmerman, 1984).

In another experiment, lysine and/or biotin were added to corn-soybean meal diets to determine their effects on pig performance from weaning to market (Hamilton and Veum, 1986). The two treatments with added lysine (L-lysine.HCL) were 0 and .2%. Pigs fed the additional lysine had average daily gains (ADG), average daily feed intakes (ADFI) and gain:feed (G:F) ratios that were greater than pigs fed diets without additional lysine in the starter and grower periods (Hamilton and Veum, 1986).

Maynor and Seerley (1986) reported an improvement in daily gain and feed conversion by feeding higher levels of energy (3.12, 3.32 and 3.52 Mcal/kg ME) and lysine (.61, .71 and .81%). The increase in energy level was attained by changing the percentage of corn in a corn-soybean meal diet and by adding 4.5% animal fat to three diets. Lysine was added to the basal diet at .1 and .2%. In this experiment, it appeared that lysine level had a greater effect on rate of gain and energy level had a greater effect on feed conversion (Maynor and Seerley, 1986). In another experiment, pigs fed a corn-soybean-dried whey (10% added whey) diet tended to consume more feed (464 vs 448 g/day), gained faster (254 vs 236 g/day) and were more efficient (1.84 vs 1.91) than pigs fed a corn-soybean diet alone (Stahly et al., 1982).

Lewis et al. (1981), fed diets to weanling crossbred pigs, containing two levels of fat and six levels of lysine, to determine the lysine requirement of young pigs fed practical diets with and without added fat. With the addition of fat there was a decrease in feed intake, an increase in feed efficiency and no change in average daily gain. The increased lysine levels in the diet significantly improved average daily gain and feed efficiency, but tended to increase feed intake (Lewis et al., 1981).

III. Fat Utilization

In the past, several experiments have been performed to compare the use of different sources and/or types of fat on the performance of weanling pigs. In a trial involving the comparison of added dietary poultry and animal fat, neither source nor level of fat influenced average daily gains (Seerley et al., 1978). Feed efficiency was not different between fat sources, but increasing the level of added fat supported an improvement in the feed:gain ratio. Asplund et al. (1960), fed white grease and corn oil to baby pigs. Pigs fed the grease exhibited no advantage in weight gain, feed efficiency or energy conversion over controls. They also found that animals fed the corn oil gained more slowly and less efficiently than pigs fed the control diets.

Lard (10%) was added to two sets of diets (Aherne et al., 1982). Feed intake was not reduced with the addition of 10% lard when protein, vitamins and mineral levels of the diet were increased and nutrient-calorie ratio was maintained. However, the addition of lard to an adjusted starter diet improved average daily gain and feed conversion efficiency. When lard was added to unadjusted diets, there was a slight reduction in feed intake and no improvement in performance as compared to pigs fed the control diet(Aherne et.al., 1982).

Adams and Jensen (1984) compared the utilization of in-seed fats (fats in high-oil corn, roasted soybeans and sunflower seeds) and the respective extracted fats (corn oil, soybean oil and sunflower seed oil) by the young pig. The average fat digestibility for the in-seed fats was less than for the extracted fats. There were no significant differences in corrected fat digestibilities among the in-seed fats, but there was a significant interaction between source and form of fat (Adams and Jensen, 1984).

IV. <u>Effect of Dried Whey and Fat on Performance</u>

Martino and Mahan (1983) fed a dried whey diet to weanling pigs for various time lengths to determine the effect on performance and nitrogen balance responses. Animals consuming the dried whey diet had higher growth rates and feed intakes as time of access to the diet increased. Nitrogen retention was enhanced to a greater extent with lighter initial pig weaning weights than for heavier animals at weaning with the dried whey addition. In another study, the inclusion of 20% dried whey in a corn-soybean meal diet resulted in no increases in rate of gain or feed consumption and no improvement in feed efficiency (Wahlstrom et al., 1986). Armstrong et al. (1981), reported a reduction in daily feed intake, and a decrease in feed to gain ratio with fat addition, while addition of dried whey resulted in improved pig performance as compared to a corn-soybean meal diet.

The addition of whey protein concentrate (WPC) at the rate of 16.2 or 33.7% to an isonitrogenous and isocaloric corn-soybean meal diet improved growth rates of pigs when compared to pigs fed the control diets (corn-soybean-fishmeal diets)(Cinq-Mars et al., 1986). Feeding WPC improved feed-to-gain ratios by about 40%. Feed intake, expressed as a percent of body weight, was 6.2% for controls and 5.0% for WPC-fed piglets (Cinq-Mars et al., 1986).

V. Fat and Environment

During the winter, in total confinement swine operations, it may be necessary to add fat to the diet in order to control amounts of dust produced by the feed. This added fat may also help in the improvement of the pigs performance because of the lack of dust. Gore et al. (1986), performed an experiment to determine the effects of soybean oil on nursery air quality and performance of weanling pigs. With the addition of 5% soybean oil to a basal corn-soybean meal diet, settled dust was reduced by 45 to 47%. With added soybean oil, average daily feed intake exhibited a tendency toward reduction, while feed efficiency was improved. Added soybean hulls increased average daily feed intake and feed to gain ratios (Gore et al., 1986).

McNutt and Ewan (1984), found that the efficiency of dietary energy and N (nitrogen) utilization for carcass energy and N gains increased quadratically with increasing feed intake. In another set of experiments, involving pigs housed either individually or in groups of four under pen conditions, they also found the same type of results. Other experiments, with different energy levels and environmental temperatures, demonstrated that the efficiency of metabolizable energy for energy retention or live weight gain improves as the energy concentration of the diet is increased under thermoneutral conditions (Noblet et al., 1985).

VI. Interaction of Energy and Protein

Energy and protein interactions have been studied using different dietary energy sources such as added animal or vegetable fats or vegetable oils such as corn oil. With added dietary levels of corn oil, there was a significant linear and quadratic response for average daily feed intake (McConnell et al., 1982). As fat level within the diet increased, feed intake as well as daily caloric intake decreased. Feed efficiency was improved with an increase in added fat levels in the diet (McConnell et al., 1982).

With an increase in calorie:protein ratio in the diet of baby pigs, feed intake and gains decreased through the second week of a four-week trial. However, during the third and fourth week rate of gain increased and feed efficiency improved (Leibbrandt et al., 1975). Protein level in the diet caused no difference in average daily gain or feed:gain ratio, but as added fat levels increased within the different protein diets, there was a linear increase in average daily gain and an improvement in feed efficiency (Keaschall et al., 1981).

Campbell (1977) using protein levels of 15.0, 17.2, 19.1, 21.4 and 23.2% in a high energy diet fed to early weaned pigs, reported significant improvements in growth and feed conversion when protein was increased from 15.0 to 19.1%.

The addition of fat increases the caloric density of the diet and therefore decreases feed intake (Allee, 1985). Because of the reduced feed intake there is a reduction in intake of other nutrients which may be the reason for reductions in gain of pigs. When pigs were fed diets with different added fat levels and a constant calorie:protein ratio feed intake decreased and feed efficiency improved, while average daily gain remained similar. However, when the calorie:protein ratio was not held constant, gains were slower and feed:gain ratio increased (Allee, 1985).

Haydon (1986) indicated that an increase in dietary lysine concentration from .67 to .76% tended to linearly improve average daily gain of pigs. Average daily feed intake (ADFI) tended to linearly decrease with increasing lysine levels for soybean meal diets and was similar for L-lysine (L-lysine.HCL) fed pigs (Haydon, 1986). Therefore, there was a tendency for daily ME intakes to decrease with increasing lysine concentrations for the soybean meal diets. With increasing lysine levels, feed efficiency tended to improve (Haydon, 1986).

Leibbrandt et al. (1975), demonstrated that dietary source of fat had no effect on total weight gain of baby pigs, but as fat level was increased from 5 to 10%, weight gain decreased. Growing pigs fed diets containing 10% fat had greater weight gains than pigs fed diets with 5% fat. There was no effect of source of fat on weight gains. Feed efficiency of growing pigs was improved as fat level was increased from 5 to 10% (Leibbrandt et al., 1975).

Weanling pigs fed diets with or without mycotoxin contaminated corn and with or without added fat, at different crude protein (CP) levels, performed differently (Coffey, 1986). Pigs fed 18% CP diets with mycotoxin contaminated corn had a reduced average daily gain (ADG) and an increased feed to gain (F/G) ratio, while performance of pigs fed 20% CP was not affected. When 5% poultry fat was added to the diet containing mycotoxin contaminated corn, feed intake depression was prevented (Coffey, 1986).

Myer and Combs (1983) reported that feed efficiencies of a corn diet, as well as non-bird and bird-resistant grain sorghum-based diets, were improved for young, starting pigs by addition of three percent fat. Improvement in feed efficiency tended to be greater for grain sorghum-based diets than for the corn-based diet (Myer and Combs, 1983).

According to Mahan and Maxson (1984), pigs fed diets with a 7.5% supplemental animal-vegetable fat source had no improvement in growth rate when compared to pigs fed a corn soybean meal diet with no added fat. With the added fat, feed intake was lowered and feed efficiency was improved. The initial weight of the pigs affected performance, with the heavy weight weanling pigs showing a superior performance compared to the light weight weanling pigs (Mahan and Maxson, 1984).

Owsley et al. (1986), fed pigs a corn-soybean meal based diet with added dried whole whey, lard or dried skim milk to determine the effects on nutrient digestibilities in the young pig. Dry matter digestibility and energy digestibility were higher for pigs fed the basal diet with added dried skim milk or dried whey, than for those pigs fed the basal or corn-soy plus lard diets. Animals fed dried skim milk had improved nitrogen digestibility over those fed other dietary treatments (Owsley et al., 1986).

VII. Fat and Antibiotics

Fat plays a similar role, in its effect on improving pig performance, as do antibiotics. The addition of fat to grain sorghum diets fed to starting, growing and finishing swine improved feed efficiency by lowering feed intake while the overall average daily gain (ADG) of pigs fed diets with or without fat did not differ (White et al., 1986). In another study, the addition of 5% soy hulls, to the basal corn-soybean meal diet, increased average daily feed and ADG during the starter phase compared to diets without soy hulls (Jewell and Veum, 1981). Five percent added dietary soy hulls increased average daily feed intake (ADFI) and average daily gain (ADG), while 10% added soy hulls decreased ADG and ADFI (Jewell and Veum, 1981).

CHAPTER 3

MATERIALS AND METHODS

I. Experimental Animals and Treatments

Experiment 1. 56 Landrace X Hampshire X Duroc crossbred weanling pigs weighing an average of 17.1 kg, and 56 days of age were allotted to 7 dietary treatments in experiment 1. Compositions of diets used in this experiment are presented in Table 1. Eight pigs were randomly assigned to receive each of the 7 experimental diets. These diets were fed for a two-week period.

Experiment 2. For experiment 2, 54 Landrace X Hampshire X Duroc crossbred pigs were utilized to determine the effects of source of fat and the addition of synthetic lysine (L-lysine.HCL) to a basal corn-soybean meal diet which was formulated to contain .8% lysine and 2732 kcal ME/kg. The diets were formulated to provide a group of three control diets (with no added fat), three diets with 5% added dry fat (Soweena 4-80) and three diets with 5% added liquid fat (Flofat) (for the composition and description of Soweena 4-80 and Flofat see Table 2). Within the three sets of diets containing varying levels and/or types of fat the proportion of lysine varied from a low of .80% to a high of 1.10% with an intermediate level of .95%. The first diet of each group contained no added lysine, but the second and third diets contained an additional .15 and 0.30% lysine, respectively. Corn and soybean meal (SBM) were kept constant throughout all nine diets, to insure the same level of all other essential and non-essential amino

TABLE 1. DIET COMPOSITION FOR EXPERIMENT 1[a]

Diets	1	2	3	4	5	6	7
		Liquid Fat (Flofat)[d]			Dry Fat (Soweena 4-80)[e]		
Item	Basal	1%	2%	3%	1.016%	2.032%	3.048%
Corn	67.55	66.33	65.10	63.85	66.41	65.26	64.12
SBM 48	29.45	29.67	29.90	30.15	29.57	29.71	29.83
Dical PO_4	.97	.99	1.00	1.01	.99	1.00	1.02
Limestone	.91	.91	.90	.90	.91	.90	.89
Salt	.50	.50	.50	.50	.50	.50	.50
VTM[b]	.86	.86	.86	.86	.86	.86	.86
Antibiotic[c]	.10	.10	.10	.10	.10	.10	.10
Lab analysis: as-fed basis:							
dry matter	88.25	88.44	88.77	88.67	88.50	88.69	89.51
crude protein	21.11	20.96	21.78	19.90	20.55	21.60	19.93
ether extract	1.99	2.51	3.34	3.80	2.97	3.59	4.23
metabolizable energy Kcal	3448	3503	3520	3622	3521	3576	3585

TABLE 1 (continued)

[a]All items for each diet are given as a percentage of the diet.

[b]Vitamin-trace mineral premix provided the following quantities per kg of diet: 10,371 USP Vitamin A; 1,886 ICU Vitamin D3; 18.86 IU Vitamin E; 7.54 mg riboflavin; 22.63 mg dPantothenic acid; 37.7 mg niacin; 9.43 ug Vitamin B12; 3.77 mg Vitamin K (MSBC); 377 mg choline chloride; 154 mg Zn; 103 mg Fe; 68.6 mg Mn; 10.3 mg Cu; .685 mg I; .086 mg Se.

[c]Antibiotic: ASP250 added at .35 lb/350 lbs .1% of the diet, ASP250 supplied 40 grams chlortetracycline, 40 grams sulfamethazine and 20 grams of penicillin.

[d]Liquid fat (Flofat) composition see Table 2.

[e]Dry fat (Soweena 4-80) composition see Table 2.

TABLE 2. COMPOSITION OF FATS USED IN EXPERIMENTS 1 AND 2

Flofat[a]	Soweena 4-80[b]
Description: Flofat is a liquid fat which is a combination of animal and vegetable fats.	Description: Soweena 4-80 is a fat which is a choice white grease encapsulated in a thin layer of corn syrup solids and milk protein (casein).
Calculated Calories: Calories 8184 kcal/kg Digestible Energy 7392 kcal/kg Metabolizable Energy 7150 kcal/kg	Calculated Calories: Metabolizable Energy 7034 kcal/kg
Lab Analysis:	Lab Analysis:
As-fed basis: Dry matter 98.53 % Crude protein 2.44 % Ether extract 98.42 % Gross energy 8759 kcal/kg	As-fed basis: Dry matter 99.14 % Crude protein 3.76 % Ether extract 74.42 % Gross energy 7812 kcal/kg Lysine 0.41 %

TABLE 2 (continued)

Fatty Acid Profile:	Fatty Acid Profile:
Myristic 0.06 %	Caprylic (8:0) 0.1 %
Pentadecanoic 0.03 %	Capric (10:0) 0.1 %
Palmitic 14.80 %	Lauric (12:0) 0.9 %
Palmitoleic 0.23 %	Myristic (14:0) 1.7 %
Hexadecadienoic 0.12 %	Palmitic (16:0) 24.2 %
Margaroleic 0.05 %	Palmitoleic (16:1) 2.4 %
Stearic 3.47 %	Margaric (17:0) 0.5 %
Oleic 21.83 %	Stearic (18:0) 12.6 %
Linoleic 52.88 %	Oleic (18:1) 44.4 %
Linolenic 5.42 %	Linoleic (18:2) 10.2 %
Nonadecanoic 0.66 %	Linolenic (18:3) 0.5 %
Arachidic 0.36 %	Arachidic (20:0) 0.7 %
Gadoleic 0.06 %	
Behenic 0.03 %	

[a]Flofat produced by BNI (Better Nutrients Inc.) 5050 Poplar, Suite 1732 Memphis, Tenn. 38157.

[b]Soweena 4-80 produced by Merrick Foods, Inc. The Baby Animal Nutrition Specialists P.O. Box 307, Middleton, WI 53562.

acids, with dextrose added as a filler to bring the total to 100% for each diet. Dry fat and liquid fat diets were formulated to be isocaloric for ME and isonitrogenous except for the added lysine. The caloric content, of the diets to which fat was added, was based on metabolizable energy values (ME) of the two fat sources respectively. Pigs used in this experiment averaged 11.24 kg and were about 49 days of age. Six pigs were randomly allotted to each of the nine treatments. Composition of the respective diets is listed in Table 3. The diets were fed for a 3-week period. Composition of the fats used in this study are listed in Table 2.

II. Facilities

Animals in both experiments were individually housed in expanded metal pens measuring 76 centimeters (cm) in length X 60 cm in width X 57 cm in height. Animals were fed ad libitum and feed was added twice daily. They were provided a constant source of water using nipple waterers.

III. Dates and Sample Collection

Pigs in experiment one were weighed on a weekly basis. They were fed from individual self feeders. Buckets for storing feed for each individual pig were weighed at the beginning and end of each week. Weekly feed samples were obtained for crude protein (CP), ether extract (EE), dry matter (DM) and gross energy (GE) analyses, (AOAC, 1975). Pigs in experiment 2 were weighed on a weekly basis and feeding procedure and facilities were similar to those used in experiment 1.

TABLE 3. DIET COMPOSITION FOR EXPERIMENT 2[a]

Diets	1	2	3	4	5	6	7	8	9
Fat	No Added Fat			5% Dry Fat[c]			5% Liquid Fat[d]		
Lysine[b] Item	.8	.95	1.1	.8	.95	1.1	.8	.95	1.1
Corn	68.65	68.65	68.65	68.65	68.65	68.65	68.65	68.65	68.65
SBM 48	19.35	19.35	19.35	19.35	19.35	19.35	19.35	19.35	19.35
Fat	-----	-----	-----	5.16	5.16	5.16	5.08	5.08	5.08
Lysine[e]	-----	.192	.385	-----	.192	.385	-----	.192	.385
Dextrose	5.91	5.718	5.525	3.25	3.058	2.865	.83	.638	.445
Dical PO_4	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56
Limestone	.68	.68	.68	.68	.68	.68	.68	.68	.68
Salt	.50	.50	.50	.50	.50	.50	.50	.50	.50
VTM[f]	.60	.60	.60	.60	.60	.60	.60	.60	.60
Antibiotic[g]	.25	.25	.25	.25	.25	.25	.25	.25	.25
Lab analysis: as-fed basis:									
dry matter	89.21	88.57	88.97	89.42	89.88	89.40	89.94	89.80	90.18
crude protein	16.42	16.33	16.52	15.82	16.11	16.24	16.76	16.41	16.93
ether extract	2.00	2.26	2.10	6.57	7.47	7.24	7.23	7.25	7.37
metabolizable energy Kcal	3421	3382	3402	3594	3655	3632	3673	3660	3654

TABLE 3 (continued)

[a]All items for each diet are given as a percentage of the diet.

[b]Lysine levels as percent of diet.

[c]Dry fat (Soweena 4-80) composition see Table 2.

[d]Liquid fat (Flofat) composition see Table 2.

[e]Lysine as L-Lysine.HCL - 78% Lysine.

[f]Vitamin-trace mineral premix provided the following quantities per kg of diet: 10,371 USP Vitamin A; 1,886 ICU Vitamin D3; 18.86 IU Vitamin E; 7.54 mg riboflavin; 22.63 mg dPantothenic acid; 37.7mg niacin; 9.43 ug Vitamin B12; 3.77 mg Vitamin K (MSBC); 377 mg choline chloride; 154 mg Zn; 103 mg Fe; 68.6 mg Mn; 10.3 mg Cu; .685 mg I; .086 mg Se.

[g]Antibiotic: ASP250 added at .875 lbs/350 lbs as .25%, ASP250 supplied 100 grams chlortetracycline, 100 grams sulfamethazine and 50 grams of penicillin.

IV. Statistical Analysis

The data were analyzed by the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS, 1985). In analysis of data from experiment one, orthogonal (single-degree of freedom) comparisons were made to evaluate the effect of adding fat to the basal diet. The model for this experiment was:

$$Yijk = mu + ti + bj*(xi - xmean) + eijk$$

where: Yijk = the dependent variables average daily gain, feed efficiency and feed consumption

mu = the overall theoretical mean

ti = treatment which is made up of different levels of fat and different sources of fat

bj*(xi - xmean) = initial weight

eijk = random error

For the second experiment, orthogonal(single-degree of freedom) comparisons were used to evaluate the effects of adding fat to the basal diet. The model for this experiment was:

$$Yij = mu+alphai+eij$$

where: Yij = the dependent variables average daily gain, feed efficiency and feed consumption

mu = the overall mean

alphai = fat source whether liquid, dry or no added fat

eij = random error

Orthogonal (single-degree of freedom) comparisons were used to evaluate the effects of adding varying levels of lysine within each of the three sets of diets. The model for this set of contrasts was :

Yijk = mu + alphai + bj*(xi - xmean) + eijk

where: Yijk = the dependent variables average daily gain, feed efficiency and feed consumption

mu = the overall mean

alphai = lysine level in the diet

bj*(xi - xmean) = initial weight

eijk = random error

This model was also analyzed utilizing orthogonal polynomials to see if there was a linear or curvilinear effect on the dependent variables ADG, feed efficiency and feed consumption due to an increase in the level of lysine in the diet.

CHAPTER 4

RESULTS AND DISCUSSION

I. Experiment 1

The performance data for experiment 1 are presented in Table 4. During the first week of experiment 1, the highest level of added liquid (Flofat) fat (3%) produced lower average daily gain (ADG) of pigs ($p < .05$) than diets containing the 2% fat level. This result is consistent with the findings of McConnell et al. (1982) who reported that 3,520 Kcal of metabolizable energy in the diet reduced gains. Diets containing the highest level of dry (Soweena 4-80) fat (3.048%) tended to produce lower ADG of the pigs ($p = .05$) during the first week than diets containing 2.032% dry fat. Initial weight of the pigs had no significant effect on the first week's ADG ($p > .05$). Neither fat source, fat level nor initial weight had an effect on ADG during the second week of the experiment ($p > .05$). When comparing dry fat to liquid fat, there was a significant decrease in overall ADG of the pigs fed the dry fat ($p < .05$) compared to those fed the liquid fat.

Initial weight affected feed efficiency (Table 4) during the first week and over the whole experiment ($p < .05$). These data are substantiated by earlier observations by Mahan and Maxson (1984), who observed that the performance of heavy weight weanling pigs was superior, throughout, the study, to that of light weight pigs. Fat source, level of fat, nor initial weight of the pigs had any effects on feed efficiency of the pigs during the second week ($p > .05$).

TABLE 4. PERFORMANCE OF PIGS IN EXPERIMENT 1

Fat[d,e]		Liquid fat (Flofat)			Dry fat (Soweena 4-80)			
Item	Basal	1%	2%	3%	1.016%	2.032%	3.048%	SE
ADG,g[a]								
Week 1[f]	554[x]	642[x]	649[x]	535[y]	555[x]	610[x]	514[y]	.076
Week 2[g]	666	650	705	701	686	620	642	.073
Overall	610[xy]	646[x]	677[x]	618[x]	621[y]	615[y]	578[y]	.049
ADFI,g[b]								
Week 1[i]	1120	1157	1221	1138	1098	1173	1101	.085
Week 2[i]	1444	1517	1524	1499	1456	1472	1415	.098
F/G[c]								
Week 1[j]	2.12	1.83	1.91	2.16	2.01	1.94	2.18	.115
Week 2[h]	2.20	2.35	2.20	2.19	2.15	2.41	2.24	.123
Overall[j]	2.11	2.08	2.04	2.16	2.06	2.17	2.19	.082

[a]Average daily gain given as mean weight in grams.

[b]Feed consumption given as mean consumption in grams.

[c]Feed efficiency given as mean per diet.

[d]Eight pigs per diet.

[e]Means in the same row followed by different superscripts are different ($p < .05$).

[f,g,h]Initial weight of the pigs had no effect ($p > .05$).

[i,j]Initial weight of the pigs had an effect ($p < .05$).

Initial weight affected feed consumption during the first and second week ($p < .05$). These results are in agreement with those of Mahan and Maxson (1984) in that they observed that heavier pigs had a superior performance as compared to lighter pigs.

Neither fat source nor fat level caused any differences in lysine consumption per kilogram of gain ($p > .05$) (Table 5). Pigs fed the basal diet consumed less energy (Table 6) than pigs fed either liquid or dry fat ($p < .05$). More energy was consumed by pigs that were fed the liquid fat diets than by pigs fed the dry fat diets ($p < .05$) (Table 6).

Pigs consuming diets containing liquid fat performed better, overall, than pigs fed diets containing dry fat. When liquid fat, (a fat source providing a slightly higher level of energy) is fed to pigs in the winter, it tends to reduce the amount of dust in the housing facility and provides more energy for the maintenance of body temperature. Feeding diets containing 2% liquid fat resulted in the greatest improvement in the performance of the pigs compared to the no-fat control diet.

II. <u>Experiment 2</u>

Experiment 2 was conducted as an extension of experiment 1. In this experiment, a total of 54 pigs were utilized, with six pigs allotted to each of the nine diets. The nine diets consisted of three sets: (1) diet 1,2 and 3 being the control diets with no added fat, (2) diets 4,5 and 6 being diets with 5% (percent) added dry fat, and (3) diets 7,8 and 9 being diets with 5% added liquid fat to be

TABLE 5. CONSUMPTION PER UNIT OF GAIN FOR LYSINE AND METABOLIZABLE ENERGY, EXPERIMENT 1

Fat[c]		Liquid fat (Flofat)			Dry fat (Soweena 4-80)			
Item	Basal	1%	2%	3%	1.016%	2.032%	3.048%	SE
Lysine consumption g/kg gain[a]								
Week 1	23	20	21	24	22	21	24	1.3
Week 2	24	25	24	24	24	27	25	1.4
Kcal ME consumed/ gm gain[b]								
Week 1	7.29	6.43	6.72	7.82	7.10	6.95	7.81	.407
Week 2	7.59	8.25	7.73	7.92	7.59	8.63	8.04	.437

[a]Lysine consumption grams per kilogram of gain given as mean per diet.

[b]Caloric consumption per gram of gain given as mean per diet.

[c]Eight pigs per diet.

TABLE 6. DAILY INTAKE OF LYSINE AND METABOLIZABLE ENERGY, EXPERIMENT 1

Fat[d]		Liquid fat (Flofat)			Dry fat (Soweena 4-80)			
Item	Basal	1%	2%	3%	1.016%	2.032%	3.048%	SE
Daily caloric[a,b] intake, kcal								
Week 1	3858	4056	4292	4122	3871	4196	3948	137.12
Week 2	4973	5320	5356	5430	5132	5265	5074	157.85
Lysine intake,g[c]								
Week 1	12.21	12.49	13.43	12.63	12.08	12.90	12.22	.425
Week 2	15.74	16.38	16.76	16.64	16.02	16.09	15.70	.490

[a]No effect of diet during week 1 or week 2 ($p > .05$).

[b]Daily caloric intake in kilocalories given as mean per diet.

[c]Lysine intake in grams given as mean per diet.

[d]Eight pigs per diet.

TABLE 7. PERFORMANCE OF PIGS IN EXPERIMENT 2

Fat[a,f]	No Added Fat			5% Dry Fat			5% Liquid fat			
Lysine Item	.8	.95	1.1	.8	.95	1.1	.8	.95	1.1	SE
ADG,g[b]										
Week 1[e]	500	411	486	577	500	503	459	435	366	58.18
Week 2[g,l,m]	607[x]	538[x]	676[x]	516[y]	621[y]	589[y]	591[z]	562[z]	535[z]	49.65
Week 3[l,m]	624	547	683	664	711	626	659	657	606	36.55
Overall[h,l,m]	577	499	615	586	611	573	570	551	502	42.82
ADFI,g[c,k,n]										
Week 1[m]	1132	938	1016	1238	978	1077	999	973	894	80.60
Week 2[m]	1445	1154	1284	1399	1228	1409	1365	1237	1208	84.34
Week 3	1448[x]	1304[x]	1479[x]	1615[y]	1488[y]	1601[y]	1592[z]	1424[z]	1311[z]	76.95
F/G[d,n]										
Week 1[i,m]	2.36	2.64	2.15	2.19	2.00	2.16	2.31	2.45	2.97	.280
Week 2[i,k,m]	2.43[x]	2.20[x]	1.93[x]	2.77[y]	1.99[y]	2.43[y]	2.39[z]	2.39[z]	2.36[z]	.173
Week 3[j,m]	2.34	2.46	2.17	2.47	2.11	2.60	2.46	2.17	2.16	.152
Overall[i,m]	2.34	2.32	2.06	2.43	2.02	2.38	2.37	2.22	2.32	.127

TABLE 7 (continued)

[a]Six animals per diet.

[b]Average daily gain given as mean per diet in grams.

[c]Average daily feed intake given as mean per diet in grams.

[d]Feed to gain ratio given as mean per diet.

[e]No effect of lysine level ($p > .05$); no effect of fat ($p > .05$); no effect of lysine levels within fat ($p > .05$); initial weight as a covariate affected weight gain of the pigs ($p < .05$).

[f]Means in same row followed by different superscripts are different ($p < .05$).

[g,h]Initial weight affected gain ($p < .05$).

[i]No effect of initial weight ($p > .05$).

[j]Initial weight affected feed efficiency ($p < .05$).

[k]Initial weight affected feed consumption ($p < .05$).

[l]Curvilinear response to lysine level within fat diets ($p < .05$).

[m]No effect of lysine or fat ($p > .05$).

[n]No effect of lysine level within fat ($p > .05$).

isocaloric, based on metabolizable energy, with the dry fat diets. Performance data for this experiment are presented in Table 7.

Pigs fed the three control diets (1,2 and 3) had a higher ADG during the second week than pigs fed either the dry fat diets (4,5 and 6) or the liquid fat diets (7,8 and 9) ($p < .05$) (Table 7). Initial weight had an effect on pig gain during week 1, 2 and overall ($p < .05$). These results agree with those obtained by Mahan and Maxson (1984) that demonstrated that heavier weight pigs gained more than lighter weight pigs. There was no effect of lysine or fat on ADG during week 1, 2, 3 or on overall gain ($p > .05$) (Table 7). There was a curvilinear response, with respect to gain, to lysine level within fat treatments during week 2, 3 and overall ($p < .05$). As lysine level increased from .80 to .95, ADG was decreased in pigs fed diets with no added fat. Increasing the lysine level from .95 to 1.10% resulted in a significant increase in rate of gain ($p < .05$). ADG during week 2, 3 and overall ADG of pigs fed the dry fat diets were similar to pigs fed diets containing .95% added lysine but decreased thereafter ($p < .05$).

The ADG of pigs fed the liquid fat diets with varying levels of lysine tended ($p = .05$) to have a linear relation with days on feed. It decreased during week 2, 3 and overall when lysine level in the diet was increased from .80 to .95 and 1.10% lysine.

During week 2, pigs fed the control diets (1,2 and 3) had a more desirable feed efficiency than pigs fed either the dry fat diets (4,5 and 6) or the liquid fat diets (7,8 and 9) ($p < .05$). Feed efficiency of pigs fed the liquid fat diets was more desirable during week 2, than that of pigs fed the dry fat diets ($p < .05$) (Table 7). For the second week, pigs fed diets with added lysine had a more desirable feed efficiency than pigs fed diets with no added lysine ($p < .05$). Hamilton and Veum (1986) obtained similar results in an experiment conducted to determine the effect of biotin and/or lysine additions to corn-soybean meal diets on the performance and nutrient balance of growing pigs. There was no effect of initial weight of the pigs on feed efficiency during week 1, week 2 or overall ($p > .05$). Initial weight affected feed efficiency during week 3 ($p < .05$) (Table 7). There was no effect of lysine, fat or lysine level within fat treatments on feed efficiency during week 1, week 3 or overall ($p > .05$). Feed efficiency during week 2 was not affected by lysine levels within fat treatments ($p > .05$) (Table 7).

Initial weight affected feed consumption during week 1, week 2 and week 3 ($p < .05$) (Table 7). Pigs fed diets (1-3) consumed less feed than pigs fed the dry fat diets, (4-6) or pigs fed liquid fat diets, (7-9) ($p < .05$), during week 3. Neither lysine nor lysine level within fat treatments affected feed consumption during week 3 ($p > .05$) (Table 7). Animals consumed more of the dry fat diets during the third week than either the liquid fat or control diets ($p < .05$) (Table 7). Feed consumption during week 1 and week 2 was not affected by lysine, fat or lysine level within fat treatments ($p > .05$).

With an increase in levels of lysine in the diets, daily consumption of lysine increased during week 1, week 2 and week 3 ($p < .05$) (Table 8). The addition of fat to the diets caused no differences in lysine consumption during week 2 or 3, compared to the

TABLE 8. DAILY CONSUMPTION OF LYSINE AND METABOLIZABLE ENERGY IN EXPERIMENT 2

Fat[a,b,c]	No Added Fat			5% Dry Fat			5% Liquid Fat			
Lysine Item	.8	.95	1.1	.8	.95	1.1	.8	.95	1.1	SE
Kcal ME consumed per day										
Week 1	3994	3315	3705	4351	3448	3921	3520	3444	3259	301.40
Week 2[e]	5085	4075	4679	4913	4331	5131	4795	4389	4403	312.28
Week 3	5094	4602	5393	5672	5256	5830	5583	5052	4776	288.67
Lysine consumption,g[d]										
Week 1	9.06[xy]	8.91[xy]	11.18[xy]	9.90[xy]	9.29[xy]	11.85[x]	7.99[y]	9.24[xy]	9.83[xy]	.772
Week 2	11.56[y]	10.96[y]	14.12[xy]	11.19[y]	11.67[y]	15.50[x]	10.92[y]	11.75[y]	13.29[xy]	.813
Week 3	11.58[z]	12.39[z]	16.27[xy]	12.92[yz]	14.14[yz]	17.61[x]	12.74[z]	13.53[yz]	14.42[yz]	.746
Calculated ME:Lysine Ratio[f,g]	439	372	331	439	372	331	439	372	331	4.57

TABLE 8 (continued)

[a]Six pigs per diet.

[b]Daily caloric consumption and lysine consumption given as mean consumption per diet.

[c]Means in same row followed by different superscripts are different ($p < .05$).

[d]Lysine levels caused a linear response within fat diets ($p < .05$).

[e]Quadratic response to lysine levels ($p < .05$).

[f]Linear response to increased lysine levels within fat diets ($p < .05$).

[g]Same ratio for all three weeks.

control diets ($p > .05$). There was a linear response in lysine consumption during the three weeks as lysine content of the diet increased ($p < .05$).

A significant linear increase in lysine consumption and lysine consumption per kg of gain occurred in response to increased dietary lysine levels during week 1, week 2 and week 3 ($p < .05$) (Table 9). There was no effect of fat level on lysine consumption per kilogram of gain during any time period within experiment two ($p > .05$).

Neither lysine or fat had any effect on metabolizable energy (ME) consumption (Table 8) or on ME consumption per gram of gain during week 1 or week 3 ($p > .05$) (Table 9). However, during week 2, lysine affected ME consumption (Table 8) and ME consumption per gram of gain (Table 9) ($p < .05$). There was a quadratic response of ME consumption and ME consumption per gram of gain to increased lysine levels during week 2 ($p < .05$). These results are similar to those of Haydon (1986) who observed that there was a tendency for decreasing daily ME intakes (Mcal/day) with increasing lysine concentrations in soybean meal based diets.

Lysine level in the diet affected the calorie to lysine ratios ($p < .05$) which decreased with increasing lysine levels within diets containing added fat and in the control diets ($p < .05$) (Table 8).

Experiment 1 was performed during winter and experiment 2 was performed in early spring when the average environmental temperature could have been higher. Performance of pigs in the second experiment was not affected to the same degree by fat source as that of pigs in the first experiment. When comparing the dry fat to the liquid fat

TABLE 9. CONSUMPTION OF LYSINE AND METABOLIZABLE ENERGY PER UNIT OF GAIN IN EXPERIMENT 2

Fat[a,b,c]	No Added Fat			5% Dry Fat			5% Liquid Fat			
Lysine Item	.8	.95	1.1	.8	.95	1.1	.8	.95	1.1	SE
Kcal ME per gram gain										
Week 1	8.33	9.34	7.82	7.68	7.09	7.89	8.07	8.71	10.82	1.245
Week 2[f]	8.55	7.73	7.03	9.73	7.00	8.85	8.38	7.94	8.60	.607
Week 3	8.26	8.62	7.90	8.70	7.45	9.47	8.62	7.70	7.88	.545
Lysine consumption grams/ kilogram gain[d,e]										
Week 1	18.9	25.1	23.6	17.5	19.0	23.8	18.5	23.2	32.7	2.7
Week 2	19.5^{y}	20.9^{xy}	21.2^{xy}	22.2^{xy}	18.9^{y}	26.7^{x}	19.2^{y}	21.3^{xy}	26.0^{xy}	1.7
Week 3	18.8^{y}	23.3^{xy}	23.8^{xy}	19.8^{y}	20.1^{y}	28.6^{x}	19.7^{y}	20.6^{y}	23.8^{xy}	1.4

[a]Six pigs per diet.

[b]Consumption of lysine and metabolizable energy per unit of gain given as mean per diet.

[c]Means in same row followed by different superscripts are different ($p < .05$).

[d]Lysine level causes a linear response within fat diets ($p < .05$).

[e]No fat effect on lysine consumption per kilogram of gain ($p > .05$).

[f]Quadratic response to lysine levels ($p < .05$).

during the second week, the pigs consumed more of the diet containing dry fat than of the diets containing liquid fat. This difference in consumption could be due to a lower energy requirement for maintenance of body temperature in the warmer environment.

CHAPTER 5

SUMMARY

Two experiments were conducted to evaluate the effect of lysine and form and level of fat on weanling pig performance. In experiment 1, 56 weanling pigs were housed individually and eight pigs were fed each of the seven different diets, a basal and six others containing 1, 2 or 3% added liquid or added dry fat. The pigs were fed twice daily an ad libitum level for two weeks. Pigs fed the dry fat diets had lower average daily gains during the experiment, than did pigs fed the liquid fat diets ($p < .05$). Initial weight affected feed efficiency ($p < .05$) and feed consumption. Metabolizable energy consumption was not affected by diet ($p > .05$). Lysine consumption per day was affected by fat source ($p < .05$).

In experiment 2, 54 weanling pigs were housed individually and each pig was fed one of the following nine diets designed in a 3 X 3 factorial arrangement utilizing 3 levels of lysine (.80, .95 and 1.10) and 3 levels of fat (0, 5% dry or 5% liquid). The pigs were fed their respective diets ad libitum twice daily for three weeks. Pigs fed the control diets had a higher average daily gain (ADG) during the second week ($p < .05$) than pigs fed either the dry fat or liquid fat diets. Initial weight had an effect on pig gain ($p < .05$). An increase in lysine level from .80 to .95% in diets with no added fat decreased ADG during the second and third week and overall compared to that of week 1 but increased ADG from .95 to 1.10% ($p < .05$). For pigs fed the dry fat diets, ADG during week 2,3 and overall increased up to the .95%

level of added lysine, and then it decreased ($p < .05$). Pigs fed the liquid fat diets tended to have ($p = .05$) a linear decrease in ADG during week 2, 3 and overall, as lysine level increased from .8 to .95 to 1.1%. Feed efficiency was improved for pigs fed the control diets compared to pigs fed either of the fat diets during week 2 ($p < .05$). Animals fed the control diets during the third week consumed less feed ($p < .05$). There was no diet effect on lysine consumption during week 1, 2 or 3 ($p > .05$), lysine consumption per kilogram of gain during week 1, metabolizable energy (ME) consumption during week 1, 2 or 3 or ME consumption per gram of gain during all three weeks.

Based on these experiments, feeding a level of added fat of 2 or 3%, seems to be the optimum added level to improve performance of weanling pigs. If fat is fed at higher levels than this then the essential amino acids need to be added to the diet in order to compensate for the lack of available nutrients.

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