EFFECT OF LECITHIN AND SOURCE AND LEVEL OF FAT IN STARTER PIG DIETS ON PERFORMANCE AND NUTRIENT UTILIZATION

by

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B.S., University of Illinois, 1983

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1985

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Acknowledgements

I would like to express my sincere appreciation to my major advisor, Dr. D. Steven Pollmann, for his invaluable assistance, guidance and encouragement throughout my graduate program. Thanks are also extended to Dr. Gary Allee and Dr. Jim Nelssen for serving on my committee.

A special thanks is also extended to the feed mill crew, farm crew and fellow graduate students who helped with the mixing of diets, care of animals and collection of data, especially Mike Johnston, Sue Pope and Betsy Newton.

Finally I would like to thank my parents, for without their love and support, this would not have been possible.

Introduction

Producers are attempting to wean pigs at 3 to 4 weeks of age as a method to maximize swine production efficiency. For this to be successful, special attention must be given to the nutrient requirements of the young pig.

It is known that the baby pig grows quite rapidly after birth on a diet consisting solely of sow's milk, which contains 30-40% fat on a dry matter basis (Perrin, 1955; Asplund et al., 1960; deMan and Bowland, 1963). There is an abrupt change at weaning to a dry, low-fat diet. The stress of weaning and sudden change in diet are responsible for a decrease in feed intake and growth. In the 1-2 weeks postweaning, many pigs lose weight and even those that do not will have a depression in growth rate (Mersmann et al., 1973; Okai et al., 1976). While much of this weight loss is made up in compensatory gain, this is a critical time and light weight or weak pigs may succumb. Therefore, it would be beneficial to minimize the stress on the baby pig by providing an adequate environment and diet at weaning.

It is apparent that the baby pig can efficiently utilize the fat in sow's milk by his increased body fat reserves while nursing. At birth the pig is approximately 2% fat, while by 2 weeks of age this has increased to 15% (Manners and McCrea, 1963). Therefore, adding fat to the starter diet may improve postweaning performance and will increase the dietary energy density during a time of typically low feed intake.

There is some controversy over the young pig's ability to efficiently utilize various sources of fat and on the benefits of adding fat, especially since it is a relatively expensive ingredient and can cause physical handling problems at high levels. The following studies were undertaken to evaluate the use of an emulsifier and source of fat on nutrient utilization by the young pig.

Literature Review

Lipase activity in the baby pig

The young pig is born with the ability to metabolize fat, but the extent of utilization of fat calories is dependent on several factors. At birth lipase activity is present and remains at a fairly constant level throughout life. Kitts et al. (1956) found the lipolytic activity of pancreatic extracts to be high in pigs sacrificed at weekly intervals from birth to seven weeks of age. From this it was suggested that if the high lipolytic activity of the pancreas was an indication of lipid hydrolyzing potential, then dietary fats could be utilized by the baby pig. Under normal in vivo conditions little ingested fat is completely hydolyzed to glycerol and free fatty acids prior to absorption. In the absence of lipolysis, absorption will occur through the lacteals of the lymphatic system but the fats must first be emulsified via bile salts. Even though lipolysis is not a prerequisite to fat absorption, a certain degree will enhance emulsification and promote more rapid and complete utilization of dietary fat.

Hartman et al. (1961) compared the lipolytic activity of nursing pigs to those weaned at one day of age. There was a slight decrease in enzymatic activity at weaning but by 6 weeks of age, the pancreatic lipase activity of the weaned pigs exceeded those nursing. The decline in activity at weaning was postulated to be due to the change in diet that contained 2% lard. Scherer et al. (1972) saw a similar decline in pancreatic lipase when weaning at 2 weeks of age. By 4 weeks of age, lipase activity had returned to preweaning levels. Pond et al. (1971) also found a significant increase in pancreatic lipase with increasing age. Although lipase per gram of pancreas decreased slightly, there was approximately a three-fold increase in total pancreatic lipase from birth to 23 days of age.

Effect of calorie:protein ratio

The calorie:protein ratio has a significant effect on performance of the starter pig when fat is added to the diet. Clawson et al. (1956), Lowrey et al. (1958), Christensen (1963) and Allee and Hines (1972a) all report decreased gains, increased metabolizable or digestible energy per unit of gain and increased fat in the carcass when protein levels were not adjusted to compensate for increased energy levels in the diet. This is due to decreased intake causing a deficiency in protein. When 0, 3, 6, 9 or 12% fat was added to the diet and calorie:protein ratio was held constant, daily gains did not differ significantly. Feed efficiency and metabolizable energy required per unit gain were improved with increasing levels of fat (Allee and Hines, 1972a). Clawson et al. (1956) saw similar results over the growing-finishing period, although a narrow calorie:protein ratio supported more rapid gains from 13 to 35 kg. Noland and Scott (1960) observed seasonal effects which influenced the calorie:protein ratio. In a winter trial, results similar to those of Clawson et al. (1956) were seen. From weaning to 35 kg, gains were depressed as energy level increased and protein remained constant. In the summer trials, increasing increments of energy resulted in faster gains and reduced feed per pound of gain at all protein levels studied. When the trials were combined, the diets with the lower calorie:protein ratios resulted in the most rapid gains for the period from weaning to 35 kg.

Kennington et al. (1958) and Boenker et al. (1960) reported no influence of calorie:protein ratio on growth, feed efficiency or diet digestibility from weaning to 60 kg. Gain and feed efficiency were increased as the level of energy increased, with protein level having little influence on gain or efficiency.

Diet form

At weaning baby pigs are commonly switched from a liquid diet to a dry diet. It would seem possible that this sudden change in physical form may have an effect on the ability of the young pig to utilize calories from fat. Frobish et al. (1969) compared the utilization of fat incorporated into liquid or dry diets for 16 d old pigs. Pigs fed the liquid diet gained more and were more efficient than those on a dry diet. The addition of fat into either diet form depressed ADG and increased the energy required per unit of gain. This effect was greater in pigs receiving the dry diets, although the difference was not significant. When intake of the dry basal diet was limited to that of the dry added fat diet, daily gain was greater without added fat. The opposite trend was observed for the liquid diets. When intake of the basal diet was limited, ADG were decreased and there was a significant increase in feed required per unit of gain without added fat.

Level of fat

The addition of increasing levels of fat to a starter diet will decrease feed consumption and generally improve feed efficiency (Kennington et al., 1958; Frobish et al., 1967, 1969, 1970; Lawrence and Maxwell, 1983). The effect of fat level on growth rate, however, has been inconsistant.

Kennington et al. (1958) and Mullins et al. (1959) reported significant linear improvements in ADG with increased fat levels up to 20%. Calorie:protein ratios were not held constant in either of these trials.

When calorie:protein ratios were held constant, Asplund et al. (1960), Allee and Hines (1972b) and Brooks (1972) observed no significant effect on rate of gain with varying levels of fat. An exception to this observation was when the fat level was increased in a low energy-high molasses diet. Pigs fed molasses with 5% added fat gained more slowly than pigs fed molasses with either 10 or 20% added fat.

Frobish et al. (1967, 1970, 1971) reported a quadratic effect on ADG with increasing levels of fat. There was a marked improvement in gain when fat level increased from 0 to 5%, but there was a slight decrease in gain by increasing the amount of added fat from 5 to 10%. Increasing the fat content from 5 to 10% also increased the energy requirement per unit of gain. In an early study by Frobish et al. (1967) maximum gains were evident with 5% added fat. Lawrence and Maxwell (1983) also observed a decrease in ADG on a 12% added fat diet when compared to 4 or 8% over a five-wk period. Adding a high level of fat appeared to be detrimental during the first two wk postweaning, as the pigs on the 12% fat diet lost weight during this time. The calorie:protein ratio was held constant and there was no significant difference in daily gains among the 0, 4 or 8% added fat treatments. The efficiency of digestible energy utilization was improved with the lower levels of fat, with the 4% diet being superior. This suggests that a small amount of added fat may be desirable in decreasing the amount of energy required per unit gain.

Source of fat

There appears to be a significant correlation between the rate of absorption and the growth rate of animals fed various fats and oils. Using male Wistar rats, Thomasson (1956) grouped several fats and oils according to their absorbability. Butterfat appeared to have the fastest rate of of absorption, followed by maize oil, cottonseed oil, beef tallow, coconut fat, soybean, sunflower, groundnut and olive oils, which were approximately equal. Sesame oil and lard were intermediate with herring, rapeseed, poppyseed and kapokseed oils all showing decreased rates of absorption. This was similar to the findings of Steenbock et al. (1936), with the exception that he found rancid lard was absorbed more quickly than cottonseed oil or coconut fat in the rat. Observations in the utilization of various fat sources by the young pig have not been as consistant.

Lard and tallow are probably the most frequently used sources of fat in starter diets, primarily because they are readily available and inexpensive. There does not appear to be any significant difference in the utilization of lard or tallow (Thrasher et al., 1959; Sewell and Miller, 1965; Liebbrandt et al., 1967). However, when Liebbrandt et al. (1967) offered weanling pigs a choice between diets containing lard or tallow, they consumed almost twice as much of the diet containing tallow (28.73 vs. 15.76 kg) over 28 days. When a third fat, hydrolyzed animal-vegetable fat (HEF), was introduced the pigs consumed twice as much tallow (27.07 vs. 14.72 kg) and over three times as much lard (34.71 vs. 10.11 kg). In all cases, the diets containing fat were preferred to the basal. This is in contrast to a study by Frobish et al. (1970) in which pigs gained significantly more on a basal diet without added fat than on diets containing 20% lard or HEF. Between the two fat sources there were differences in total gains ($P<.01$), with the pigs on the HEF-supplemented diet gaining more than those on lard (9.03 vs. 6.97 kg). Butter, coconut and vegetable oils were also compared in this same trial and there were no significant differences in feed utilization between the control and diets with added fat nor among the various fat sources. There was also no difference in fat digestibility among the sources, although digestion was significantly improved with age, increasing from 77.0 to 84.9% after 10 days on experiment. In another trial with butter, coconut oil, lard and soybean oil, pigs consuming the lard supplemented diet had greater total gains (Frobish et al., 1970). In general, lard or soybean oil diets were more efficient than those with butter or coconut oil. These results conflicted with those of a second trial and observations by Lawrence and Maxwell (1983), in which pigs fed butter or coconut oil were more efficient.

Braude and Newport (1973) reported butterfat and soybean oil to be slightly superior to coconut oil and markedly superior to tallow in apparent digestibility in pigs weaned at 2-d of age. Freeman et al. (1968) found soy oil to be superior to lard, although equal to coconut oil. No significant differences could be found between soybean oil, tallow or a mixed fat from human food wastes (Brooks, 1972) nor between soybean oil, cottonseed oil or lard added to starter diets at 2.5 or 5.0% (Yacowitz, 1953). However, Eusebio et al. (1965) reported impaired performance for pigs fed soybean oil. Two-wk old pigs fed a diet with 5 or 10% added soybean oil gained significantly less than those fed the control diet or coconut oil. The digestibility of the coconut oil was also greater than that of soybean oil (80.4 vs. 75.8%). In a second trial, the source of fat (lard, tallow or soybean oil) had no effect on feed conversion or apparent digestibility. There was a level x source interaction ($P<.05$) caused by the low digestibility of the fat in a diet containing 2.5% soybean oil. From the overall experiment, it was concluded that the young pig is relatively inefficient in utilizing soybean oil, lard and tallow, and to a lesser extent coconut oil. Jacobson et al. (1949) and Bate et al. (1946) reported similar observations in calves fed soybean oil. When soybean oil replaced butterfat in a milk diet neither growth nor general appearance was enhanced. If the soybean oil was not homogenized into the milk prior to feeding the calves lost hair on their inner thighs and muzzles and exhibited a heavy "dandruff" (Bate et al., 1946). This condition could not be attributed to infections or parasites and was not observed when the soybean oil and milk were homogenized before feeding.

Choice white grease (CWG) is a commercial source of fat that is often used to supplement swine diets. When the calorie:protein ratio was held constant, pigs fed grease gained less than those fed no added fat (Asplund et al., 1960). Pigs fed CWG gained more and were more efficient than pigs fed a corn oil-supplemented diet. Yellow grease is generally considered to have a nutrient value similar to CWG. In a study of the influence of the energy:protein ratio in swine, yellow grease was used as a fat source (Clawson et al., 1962). While it was not compared to any other fat source, performance of the pigs was reported to be excellent with an ADG of .84 kg. In poultry diets, no detrimental effects on performance have been found in comparisons of yellow grease and choice white grease, brown grease, prime tallow, No. 1 tallow and No. 2 tallow (Seidler et al., 1955; Sunde, 1956), cottonseed oil (Naber and Morgan, 1956) and lard-grease mixture or lecithin-soybean oil in combination (Carver, 1959).

Corn oil has also been evaluated as a fat source for the young pig. Corn oil supplemented diets were inferior to white grease (Asplund et al. 1960), butter (Frobish et al. 1970) and coconut oil (Lawrence and Maxwell, 1983) and equal or superior to tallow and(or) lard (Sewell and Miller, 1965; Mason and Sewell, 1967; Frobish et al., 1970, Lawrence and Maxwell, 1983).

The variation on performance between sources has led to several hypothesis based on the physical properties of fat. One of the characteristics studied was melting point. Auger et al. (1947), Crockett and Deuel (1947) and Braude and Newport (1973) suggested that an inverse relationship existed between the melting point of a fat and digestibility. Crockett and Deuel (1947) observed a marked decrease in digestibility of fats melting above 50 C in man. In rats when the melting point of hydrogenated cottonseed oil was decreased from 63 to 46 C, fat digestibility increased from 24 to 84% (Auger et al., 1947). In two later studies the relationship between melting point and digestibility could not be proved. Cheng et al. (1949) and Carroll and Richards (1958) believed the decrease in digestibility of the higher melting fats to be related to the levels of Ca and(or) Mg in the diet and reported that they did not influence the utilization of low melting fats.

Carroll (1958) and Sewell and Miller (1965) reported no difference in the utilization of saturated or unsaturated fats in the rat or baby pig, respectively. A significant inverse relationship between chain length and digestibility has been observed by several researchers. As chain length increases, the apparent digestibility of the fat decreases in the chick (Renner and Hill, 1961b), guinea pig (Lloyd and Crampton, 1957), rat (Lloyd and Crampton, 1957; Carroll, 1958) and young pig (Lloyd et al., 1957; Lloyd and Crampton, 1957). Frobish et al. (1970) also found reduced digestibility with increasing chain length although he observed the pigs fed the higher molecular weight fats to be more efficient. This is in contrast to dogs and humans, which are better able to utilize long chain fatty acids (Lloyd and Crampton, 1957). Carroll (1958) and Renner and Hill (1961) found short chain fatty acids up to C10 were completely digested. Fatty acids from C10 to C18 had progressively lower digestibility and those greater than C18 were minimally digested in the chick, hen and rat. It was also noted that mono-unsaturated fatty acids had approximately equivalent digestibilities as saturated fatty acids with 6 less carbon atoms. It appears that molecular weight is not the sole factor determining utilization of a fat source. Eusebio et al. (1965) concluded from his studies that the baby pig did not efficiently utilize coconut oil, which consists of glycerides lower in molecular weight than sow milk fat.

The digestibility of individual fatty acids has also been investigated in an attempt to determine which sources of fat could be utilized most efficiently. However, this appears to vary from one source to another. Palmitic acid (16:0) was 74% digestible in predominantly ß-esterified lard, 50% digestible in interesterified lard, 40% digestible in predominantly -esterified lard (Davis and Lewis, 1969) and 91% digestible in soybean oil (Bayley and Lewis, 1965). Stearic acid also showed variation in absorpability from 28.5% in corn oil to 78.4% in lard and 81.1% in tallow (Sewell and Miller, 1965). Low digestibility of stearic acid in rapeseed oil, coconut oil, lard and tallow have also been reported (Hamilton and McDonald, 1969). Davis and Lewis (1969) postulated that the absorption of stearic acid was dependent upon the ratio of saturated to unsaturated fatty acids in the free form. It has been suggested that the absorption of saturated fatty acids increases as the amount of unsaturated fatty acids present increases (Renner and Hill, 1961; Young, 1961) but this was later disproved by Bayley and Lewis (1965). Position of the fatty acid molecule within the glyceride molecule may also influence the extent to which it is absorbed (Davis and Lewis, 1969).

Emulsifiers

It has been theorized that a substance which would promote or enhance emulsification of a fat may be of benefit by speeding the absorption of a fat, increasing digestibility of less readily utilized fats or enabling more rapid action of lipolytic enzymes (Auger et al., 1947). Lecithin is an emulsifier.

Physical properties of lecithin

Lecithin, chemically known as phosphatidylcholine, is a naturally occurring phosphotide present in the lipid fraction of blood, the liver, spinal cord, brain and bile salts. It is a polar molecule and acts as an electron carrier, as a substrate in enzymatic reactions, as a component of biological membranes and as an energy store. The chief fatty acids present in lecithin are palmitic (16:0), stearic (18:0), arachidic (20:0) and oleic (18:1). Fatty acids smaller than lauric (12:0) are not present. A lecithin molecule consists of hydrophilic phosphate ester groups and hydrophobic fatty acid chains. This makes them surface active and led to the idea that they may play an important role as emulsifying agents in biological systems (McDonald et al., 1981).

Commercial lecithin is obtained as a by-product of soybean processing. It is a waxy, fat-like substance, yellow to brown in color and melting at 72 C. It consists of nitrogen and phosphorus, and contains 30-40% soybean oil as a carrier and 60-70% phosphatides. A typical phospholipid composition for crude lecithin would be 15% phosphatidylcholine (PC), 13% phosphatidylethanolamine (PE), 9% phosphatidylinositol (PI), 5% phosphatidic acid (PA) and 2% phosphatidylserine (PS) (Szuhaj, 1983). The ratio of these phospholipids is important for functionality. A high level of PC favors oil-in-water emulsions, whereas high PI favors water-in-oil emulsions. Consequently, processing factors, either deliberate or not, can affect lecithin's performance as an emulsifier. Commercial lecithin is also considered a fair source of vitamin E (1.3 mg/gm) and biotin (0.42 mg/gm). The vitamin E content has led to the use of lecithin as an antioxidant for various oils, lards and fat-soluble vitamins (Scharf, 1947).

Lecithin production

The recovery of lecithin from soybean oil is a relatively simple process, however, processing conditions must be carefully controlled in order to maximize utility and functionality of the lecithin. The primary method for obtaining lecithin is by degumming crude soybean oil where 1-3% water or steam is added to the oil with slow agitation to hydrate the lecithin. The hydrated gums are then removed by continuous centrifugation. The wet gums are dried either through batch or film drying. An important part of processing needed to maintain consistent quality and uniformity is the additive step. Fluidizing additives such as soybean oil, fatty acids or calcium chloride can be added to adjust viscosity and acetone insolubles. If this process is not carried out, the net product will be a highly plastic solid when cool (Szuhaj, 1983).

There are six grades of lecithin commonly manufactured, which account for only one-sixth of the lecithin products sold today. The grades and analyses are shown in table 1. There are also six catagories of upgraded lecithin products, which are as follows:

a) Clarified lecithins: These have been carefully filtered in the full miscella, crude oil, or directly as lecithin. This filtration is carried out on plate and frame filters with manual or automatic cleaning cycles.

b) Fluidized lecithins: These are made by calcium chloride addition to the gums, addition of fatty acids and vegetable oil, or the addition of special proprietary diluents.

c) Compounded lecithins: These are special purpose products made by direct addition of functional food additives like Spans, Tweens, or by the addition of industrial surface active reagents. Deoiled lecithin may be combined with selected additives to improve handling and performance.

d) Hydroxylated lecithin: This is a highly water dispersible lecithin made by reaction of hydrogen peroxide and lecithin in the presence of a weak acid like lactic or acetic acid. These mildly modified lecithins have a hign rate of functionality in water-based systems. The color is extremely light but the flavor tends to be soapy.

e) Deoiled lecithin: This can be made by contacting the crude lecithin with warm acetone. The resulting dried product is a tan-colored, waxy solid that can be made to special particle sizes and have excellent free-flowing properties.

f) Fractionated lecithin: This is made by fractionating crude lecithin directly or after deoiling. Several patented processes use short-chain alcohols to split the lecithin into alcohol-soluble lecithin. These special products have functional properties that result in their particular phosphatide compositions.

Factors affecting lecithin quality

In addition to processing, there are several factors affecting lecithin quality which occur either prior to processing or during storage of the final product. Growing season, harvesting and bean storage can all affect the quality of the soybeans and therefore, quality of the crude lecithin. While the ratio of phosphatides to oil is fairly constant, there can be variation in fatty acid composition of the lecithin due to growing conditions. Cooler weather tends to reduce levels of unsaturated fatty acids and increase linolenic acid content. Soil composition can also affect the trace mineral content of lecithin. Premature harvesting can affect the color, as well as, the amount

Table 1. Soybean Lecithin Specifications[a]

Analysis	Grade					
	Fluid natural lecithin	Fluid bleached lecithin	Fluid dbl-bleach lecithin	Plastic natural lecithin	Plastic bleached lecithin	Plastic dbl-bleach lecithin
Acetone insoluble, min.,%	62	62	62	65	65	65
Moisture, max.,%[b]	1.0	1.0	1.0	1.0	1.0	1.0
Benzene insoluble, max.,%	0.3	0.3	0.3	0.3	0.3	0.3
Acid value, max.	32	32	32	35	35	35
Color, Gardner, max.[c]	10	7	4	10	7	4
Viscosity, poise 77 F, max.[d]	150	150	150	-	-	-
Penetration, max.[e]	-	-	-	22 mm	22mm	22mm

[a]National Soybean Processors Assn., Yearbook and Trading Rules, 1981-1982.

[b]By toluene distillation for less than 2 hours (AOCS Method Ja 2-46).

[c]On a 5% solution in mineral oil.

[d]By any appropriate conventional viscometer, or by AOCS Bubble/Time Method Tq 1A-64, assuming density to be unity. Fluid lecithin having a viscosity less than 75 poise may be considered a preminium grade.

[e]Using precision cone 73525, Pentrometer 73510, sample conditioned 24 hr at 77 F.

and composition of the phosphatides. Frost-damaged beans can result in lower phosphatide yields and increase free fatty acid and chlorophyll levels. This produces lecithin which is harder to adjust for acetone insolubles (AI) and acid value. The oxidative stability of the product is also reduced. Bean storage after harvest is also critical as composition can change with age and storage conditions. More mature beans have higher phosphatidic acid and free fatty acid levels, which reduces viscosity and AI. Burnt beans will reduce lecithin yields and exposure to light and heat on split beans will induce oxidation and decomposition of lecithin (Szuhaj, 1983).

During extraction of the crude oil countercurrent solvent extraction can result in poor lecithin quality if the desolventizing temperature is too high and the oil is not properly cooled afterwards. Expeller oils tend to produce scorched lecithin and dark colors that are unbleachable. The crude oil should be stored at 43-48 C until degumming (Szuhaj, 1983).

Lecithin gums are usually collected over a period of several hours and dilute hydrogen peroxide is used to prevent bacterial spoilage. A 3% hydrogen peroxide solution is also used to bleach the lecithin and benzoyl peroxide is used to produce double-bleached lecithin. Dose levels must be carefully controlled as the hydrogen peroxide reduces the brown pigments and the benzoyl peroxide reduces the red pigments in lecithin. Elevated peroxide levels in bleached products indicate free peroxides and the elimination of all peroxide, due to elevated temperatures, will cause the lecithin to darken rapidly. Shelf-life of most lecithin products is more than one year if kept at 21 C. Physical stability can be affected by reduced temperatures and freezing will cause a separation of the oil phase. Remixing in the storage drum is usually adequate to redisperse the phosphatides (Szuhaj, 1983).

Utilization of commercial lecithin

Commercial lecithin has been reported to be the most important byproduct of the edible oil processing industry because of its functionality and wide application in food systems and industrial utility (Szuhaj, 1983). It has been used as an emulsifier, wetting agent, release agent, to adjust viscosity and as a diet supplement. In animal feeds lecithin is used as a fat emulsifier and wetting aid in calf milk replacers and in pet foods to replace eggs and add luster to the coat.

Effect of lecithin on vitamin A metabolism

The addition of lecithin to the diets of rats and man will markedly influence blood levels and liver storage depots of vitamin A (Aldersberg and Sobotka, 1943; Slanetz and Scharf, 1945). When 9-12 gms of commercial lecithin was given to seven individuals, their blood vitamin A content rose 212%, as compared to an average of 41% when no lecithin was given. The same test was repeated using defatted commercial lecithin to eliminate any possible effects from the soy oil carrier. An average rise in serum vitamin A levels was 202%. From this, Aldersberg and Sobotka (1943) concluded that lecithin enhances the absorption of vitamin A in a way similar to fat absorption.

Effect of lecithin addition on fat utilization

Since lecithin can emulsify fat and make it more dispersible in aqueous solutions, it has the potential to enhance utilization of dietary fat in the aqueous nutrient transport systems of an animal's body. It also has an energy value of 6732 kcal ME/kg (Renner and Hill, 1958) making it a possible energy source in itself.

In a study using Single Comb White Leghorn male chicks (Polin, 1980) an increase ($P<.01$) in the absorption of tallow was observed with the addition of 2% lecithin. The chicks were fed isocaloric, isonitrogenous diets containing .02, .2 or 2% soy lecithin and 0 and 4% tallow. The absorption of tallow was increased from 70% in the controls to 83% in the diet containing 2% lecithin. A lesser response was seen with .2% lecithin, but this observation could not be repeated in a second trial. Carver (1959) reported no difference in gain or feed conversion with a soybean oil-lecithin mix when compared to yellow grease or lard-grease mixtures. The addition of unbleached soy lecithin to tallow-supplemented (10%) diets at the 1 or 3% levels did not appear to change availability of the fat (Sibbald et al., 1962). However, when lecithin was added at the 2% level the mean ME value of the tallow was increased by almost one kcal (7.55 vs. 8.54). This led to the conclusion that the level of lecithin that may enhance energy utilization is very critical. March and Biely (1957) compared lecithin against Santomerse-80, another surface active reagent, on the utilization of tallow or hydrolyzed animal fat (HAF) added at 12% to chick diets. Supplementation with 0.5% lecithin had no effect on rate of growth or efficiency of feed utilization. Santomerse-80 at 0.1% depressed growth of chicks on the basal and tallow diets, but did not effect growth on the HAF-supplemented diets. Lecithin also reduced the percentage of tallow excreted as neutral fat from 3.7 to 1.5%. Although there was a difference in the amount of split and intact fatty acids excreted with the addition of lecithin, there was no appreciable improvement in the digestibility of either fat.

When 3% lecithin was added as the sole source of fat to chick diets, it was found to be practically nutritionally equivalent to prime tallow, crude soybean oil, methyl esters of vegetable fats and acidulated soybean soapstock (Bornstein and Lipstein, 1961). Overall, there was a slight tendency for crude soybean oil to be superior and lecithin to be inferior to the other fat sources but this was not significant. All of the fat suplements, including lecithin, improved growth and feed efficiency porportionally to the increased fat content of the diets.

The addition of soy lecithin to cottonseed oil or hydrogenated cottonseed oil-supplemented diets markedly lowered the incidence of diarrhea and improved the digestibility of the fat when fed to rats (Auger et al., 1947). Cottonseed oils were added at 15% of the total diet. Auger et al. (1947) found when fat was added without lecithin, 40% of the rats developed diarrhea as compared to only 10% when fat and 3% lecithin were fed in combination. The digestibility coefficients of the cottonseed oils were increased from 24 to 44%, 69 to 83% and 84 to 88% in the fat samples melting at 63, 54, and 46 C, respectively. The authors provided three possible explanations as to why crude soy lecithin may increase absorption rate of fats. First, lecithin may be preferentially absorbed from the fat-lecithin mixture at a faster rate than the balance of the fat. This is not likely in a homogeneous mixture, however. Second, it may be possible that the lecithin could not be recovered from the gut by the flushing with diethyl ether procedure used. Third, it is possible that lecithin promotes absorption of a fat by increasing the speed and degree of emulsification. They concluded that the action of lecithin must be related to its speeding up the rate of absorption.

Aldersberg and Sobotka (1943) also report an increased rate of fat absorption with the addition of 10-15 g commercial soy lecithin to the diet of human subjects. The average increase was 39%. In subjects suffering from sprue, in which there is no fat absorption, the addition of lecithin caused a moderate absorption averaging 27%. When lecithin was fed without the usual fat-containing meal there was no increase in blood lipid levels.

Gregg (1932) reported that lecithin, administered either orally or intravenously to dogs, had a specific dynamic effect much less than that of an isocaloric amount of neutral fat. When given intravenously at amounts up to 1 gm/kg body weight, it had no calorigenic effect. However, the source of lecithin used in this study was derived from beef spinal cord or egg yolk, not soybeans as in the other studies reported.

When 2% soy lecithin was added in combination with 3% feed grade fat to the diets of lambs, there was a decrease in protein digestibility (Perry and Stewart, 1979). There was no effect on crude fiber or dry matter digestibility. Butter-lecithin and cottonseed oil-lecithin mixtures have been shown to support growth in dairy calves without adverse effects (Kastelic et al., 1950) although no benefits were reported. Egg lecithin added at .25 or .50% to corn oil or coconut diets was inferior to butterfat alone. Lecithin did greatly improve the appearance of the hair coat in dairy calves (Schantz et al., 1940).

There have been relatively few studies on the effect of lecithin addition to the diets of young pigs. Those reported have shown no significant improvements in fat utilization or average daily gain (Sheffy et al., 1951; Hanson et al., 1954; Frobish et al., 1969). When 1% lecithin was added in combination with 9% lard oil to the diets of 15-d old pigs, there was no difference in total gain (5.10 vs. 5.11 kg) or feed efficiency (1.94 vs. 1.95). Apparent fat digestibility at 25 days of age was slightly improved from 74.39 to 77.90% with the addition of lecithin, although this increase was not significant (Frobish et al., 1969). It may be that this level of lecithin was too low to exhibit any effect on fat utilization. However, sow's milk fat contains only 1-2% phospholipid (Sheffy et al., 1951). Stahly et al., (1983) postulated that his observation of enhanced fat utilization in starter pig diets containing spray-dried whey may partially be due to the natural lipase and/or lecithin present in whey.

Lecithin has been shown to beneficial when feeding colostrum-deprived newborn pigs raised artifically (Sheffy et al., 1951). They concluded that pigs could survive on milk that was homogenized with a lard-5% lecithin mixture. Newborn pigs offered lard-supplemented milk without added lecithin scoured severely, became dehydrated, weak and died in 4-5 d. The colostrum-fed pigs on the same treatment (no lecithin) had less diarrhea the first week and ADG were equal to those fed lecithin. Fat particle size had no effect on the efficiency of feed utilization in 2-d old pigs fed fat-lecithin homogenized milk diets.

Effect of fat addition on nutrient utilization

Inclusion of fat into swine diets will improve dry matter digestibility (Lowry et al., 1958; Greeley et al., 1964), percent ether extract (Asplund et al., 1960, Frobish et al., 1967, 1969; Liebbrandt et al., 1975) and generally increase efficiency of energy utilization (Kuryvial et al., 1962; Tribble et al., 1979). However, in a study comparing corn oil, lard, and tallow (Sewell and Miller, 1965) no differences in gross energy digestibilty were found.

The effects of fat addition on protein digestibility have been conflicting. Lowry et al. (1958), Asplund et al. (1960), and Tribble et al. (1979) all reported increased crude protein digestibility in diets with fat as compared to those without fat. However, Tribble et al. (1979) noted decreasing digestibility of crude protein as fat levels increased from 4 to 8%. Several studies also report no effect of protein digestibility with the addition of fat to the diets of swine (Sewell and Miller, 1965) and rats (Metta and Mitchell, 1956).

Poultry studies have also found the addition of fat as an oil to increase the folic acid requirement (March and Biely, 1954) and fat digestion to decrease with increasing calcium intake (Fedde et al., 1960).

The research reviewed indicates that there is no single factor which determines the extent of utilization of fat, but rather a combination of factors which are interrelated. The research reported herein was designed to study the effects of two of these variables, the use of an emulsifier and differences in saturation among fat sources, on nutrient utilization in the weanling pig.

Materials and Methods

Animals

Crossbred pigs were used in these trials from the Kansas State University swine herd with weaning age ranging from 17 to 27 d, with the average being 22 d. Pigs in trials 1 and 2 were randomly allotted and started on test 1 wk postweaning. Those in trial 3 were allotted randomly within 3 weight blocks and started on test immediately after weaning. No additional medication was given to any animal in trial 1 once the experiment was begun. In trial 2, gentamycin[1] was given via a water medicator for days 3-5 postweaning and all pigs received 200 mg long-acting oxytetracycline[2] 4 wk postweaning in an attempt to stop the spread of a severe skin disorder. Any pigs showing skin lesions were also washed in an iodine solution[3] for 3 consecutive days. In trial 3, gentamycin was given via water medicator on days 3-5 postweaning and no other medication was administered.

Housing

Pigs were weaned into an environmentally controlled nursery with woven wire flooring. Pens were 1.2 x 1.5 m and equipped with a nipple waterer. Pigs were housed 4 7 and 6 per pen in trials 1, 2 and 3 respectively. The temperature in the nursery was maintained at 34 C the first wk and dropped 1 C per wk thereafter. Plastic 4-hole feeders were used for all trials.

Pigs used in the digestion study were housed in individual metabolism crates which allowed for separate collection of feces and urine. Each crate had separate troughs for feed and water. Room temperature was maintained at approximately 30 C.

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[1] Garacin®, Continental Animal Health, Omaha, NE., 68103.

[2] LA-200®, Pfizer, Lee's Summit, MO., 64063.

[3] Betadine®, Purdue Fredrick Co., Norwalk, CT., 06856.

Diets

All diets were formulated to contain constant Kcal ME:g protein and g protein:g lysine ratios. In the fat-supplemented diets, fat was treated as a fixed ingredient and the diet was formulated to have an increased protein level when compared to the control. Unbleached soy lecithin (table 2) was added to the diets at the expense of 1.5 or 3.0% wheatstarch, accordingly. All fat sources were analyzed for fatty acid composition (table 3) by a commercial laboratory to aid in later interpretation of the data. Diets were mixed at the KSU feed mill and fed in a meal form. In trials 1, 2, and 3 feed was offered ad libitum. In the digestion study a constant amount of feed and water was offered in two equal feedings per d, approximately 9 h apart.

General Procedure

Growth Trials

Pigs were weighed and vaccinated against atrophic rhinitis the afternoon prior to weaning. At weaning, the pigs were placed into their assigned pens and had access to either a commercial starter diet for 1 week (trials 1 and 2) or the experimental diet (trial 3). Pigs were checked on a daily basis and any feeders with feed that had bridged were adjusted manually. Pigs and feeders were weighed every other wk. Any pig that died prior to being placed on the experimental diet in trial 1 or 2 was replaced with one of similar wt and age. When a pig died after the initiation of the experiment the feeder was reweighed and feed consumption per pig was calculated. Consumption for the dead pig(s) was then subtracted from the total feed consumed for the pen. The adjusted consumption was then added to the amount of feed consumed for the pen until the next weighing and feed efficiency calculated based on the lesser number of pigs.

Digestion Trial

Fifteen barrows, averaging 5.45 kg, were chosen from the third weaning group for use in a digestion study. They were weaned into the nursery and fed a commercial starter diet for 4 d. At this time, twelve barrows were randomly chosen and moved into individual metabolism crates. The pigs were allowed a 5-d adjustment for each 5-d collection period. The amount of feed given was equal to the maximum amount all pigs in the group would consume by the next feeding period. Ferric oxide (approximately 55 g) was fed as a fecal marker at the beginning and end of each collection period. Feces were collected daily and stored in a freezer. The entire 5-d collection was weighed and dried in a forced air oven at 50 C for 5 d. The sample was then reweighed and ground in a Wiley mill equipped with a 40-mesh screen. Samples were analyzed for dry matter, crude protein, ether extract and energy using procedures outlined by A.O.A.C. (1980). Diet samples were also analyzed for energy in an oxygen bomb calorimeter. Urine was collected in a 5-liter container to which 10 ml of 2N HCl was added daily. Total volume was measured at the end of 5 d and a 400 ml sample was obtained for analysis of N-retention as outlined by A.O.A.C. (1980).

Trial 1. A 35-d growth trial was conducted to determine the level and effects of lecithin addition to starter pig diets with or without added fat (table 4). One-hundred twenty crossbred pigs averaging 6.0 kg were randomly allotted to 30 pens representing 5 replications of 6 dietary treatments (2x3 factorial):

A. Corn-soy fortified basal diet

B. Basal + 1.5% soy lecithin

C. Basal + 3.0% soy lecithin

D. Basal + 4% choice white grease

E. D + 1.5% soy lecithin

F. D + 3.0% soy lecithin

Data were analyzed as a complete randomized block design by least square analysis of variance according to the General Linear Models procedure of the Statistical Analysis System (SAS, 1982).

Trial 2. A second growth trial was conducted to determine the effects of soy lecithin addition to a starter pig diet containing 20% spray-dried whey and 0 or 4% added fat (table 5). Two hundred ten crossbred pigs, averaging 6.6 kg, were randomly allotted to 30 pens representing 5 replications of 6 dietary treatments (2x3 factorial). Treatments were identical to those of trial 1, with the exception that all diets now contained spray-dried whey. The trial lasted 33 d.

Data were analyzed as a complete randomized block design by least square analysis of variance according to the General Linear Models procedure of the Statistical Analysis System (SAS, 1982).

Trial 3. A 42-d growth trial was conducted to evaluate the addition of a saturated, unsaturated, or mixed source of fat on pig performance (table 6). All diets contained 20% spray-dried whey. One-hundred sixty-eight pigs were randomly assigned to treatments based on weaning weight. The first group averaged 3.7 kg, the second group 4.9 kg and the third 5.9 kg. Overall, there were 7 replications of 4 dietary treatments; 2 within the first and third groups and 3 within the second.

A. Corn-soy fortified basal diet

B. Basal + 4% choice white grease

C. Basal + 4% soy oil

D. Basal + 2% choice white grease + 2% soy oil

The trial lasted 42 d.

Data were analyzed as a randomized complete block design using weight as the block by least square analysis of variance according to the General Linear Models procedure (Goodnight et al., 1982) of the Statistical Analysis System.

Trial 4. A digestion trial was conducted to determine the dry matter, crude protein, fat and energy digestibility when choice white grease, soy oil or a combination thereof was added to a corn-soy basal diet. Twelve crossbred barrows, averaging 5.45 kg were used. Pigs were randomly allotted to treatments and fed for one period (10 d), after which treatments were reallotted and fed for a second period (crossover design). Intake was 100 g feed and 250 ml water fed twice daily for the first period and 190 g feed and 450 ml water fed twice daily for the second period. Diets were identical to those used in trial 3.

Data were analyzed as a two-period crossover design by least square analysis of variance acording to the General Linear Models procedure of the Statistical Analysis System (SAS, 1982).

Table 2. Analysis of Unbleached Lecithin[a]

Physical and Chemical Requirements

	Limits
Moisture, % max.	1.0
Acid number	28-32
Acetone insoluble, % min.	62.0
Benzene insoluble, % max.	.10
Viscosity (G-H)	65-85 strokes
Color-Gardner (1-20 dilution, 5% solution in white mineral oil)	10 max.

General Appearance

Color	Yellow-Brown	Visual
Odor	bland in odor bland in flavor	Organoleptic

[a]Merrick Foods, Union Center, WI.

Table 3. Fatty Acid Profiles for Lecithin, Choice White Grease and Soy Oil[a]

Chain length	Percentage Composition		
	Choice White Grease	Lecithin	Soy Oil
10:0	.05	-	-
12:0	.07	-	-
14:0	1.21	.08	.07
15:0	.03	.11	.01
16:0	22.99	16.10	10.40
16:1	3.26	-	.17
16:2	.76	.11	.09
17:1	.85	.03	.04
18:0	13.87	4.13	4.22
18:1	43.20	17.81	24.71
18:2	10.24	54.18	52.19
18:3	1.71	7.01	7.70
20:0	1.00	-	-
20:1	.57	-	.01
20:4	.21	.38	-
22:0	-	.08	.05
24:0	-	-	.30
	100.02	100.02	99.99

[a]Analysis of fatty acids conducted by Woodson-Tenant Laboratories, Des Moines, IA.

Table 4. Diet Composition for Trial 1

Ingredient,%	586A	586B	586C	586D	586E	586F
Corn (IFN 4-02-935)	63.4	63.4	63.4	55.6	55.6	55.6
Soybean meal,44% (IFN 5-04-604)	29.4	29.4	29.4	33.2	33.2	33.2
Wheat starch	3.0	1.5	0	3.0	1.5	0
Choice white grease	0	0	0	4.0	4.0	4.0
Soy lecithin[a]	0	1.5	3.0	0	1.5	3.0
L-lysine HCl	.35	.35	.35	.35	.35	.35
Dical (IFN 6-01-080)	1.6	1.6	1.6	1.6	1.6	1.6
Limestone (IFN 6-02-632)	1.05	1.05	1.05	1.05	1.05	1.05
Salt (IFN 6-02-632)	.25	.25	.25	.25	.25	.25
Trace mineral premix[b]	.10	.10	.10	.10	.10	.10
Vitamin premix[c]	.50	.50	.50	.50	.50	.50
Selenium premix[d]	.10	.10	.10	.10	.10	.10
ASP-250	.25	.25	.25	.25	.25	.25
	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrient values						
% Protein	18.58	18.58	18.58	19.55	19.55	19.55
% Lysine	1.26	1.26	1.26	1.37	1.37	1.37
% Ca	.85	.85	.85	.86	.86	.86
% P	.70	.70	.70	.70	.70	.70
g protein:g lysine	14.75:1	14.75:1	14.75:1	14.27:1	14.27:1	14.27:1
Kcal ME:g protein[e]	17.18	17.40	17.62	17.14	17.35	17.56

[a]Merrick Foods, Union Center, WI.

[b]Provided the following in the complete diet (ppm): Mn, 50; Zn, 100; Fe, 100; Cu, 10; I, 3 and Co, 1.

[c]Provided the following per kg of complete diet: vitamin A, 4,410 IU; vitamin D_3, 330 IU; vitamin E, 22 IU; riboflavin, 5 mg; d-pantothenic acid, 13.2 mg; niacin, 27.5 mg; vitamin B_{12}, 24.3 µg and choline chloride, 508 mg.

[d]Provided 200 µg Se per kg complete diet.

[e]Lecithin, 6.7 Mcal/kg (Renner and Hill, 1958); choice white grease, 7.7 Mcal/kg; wheat starch, 4.0 Mcal/kg.

Table 5. Diet Composition for Trial 2

Ingredient,%	588A	588B	588C	588D	588E	588F
Corn (IFN 4-02-935)	46.66	46.66	46.66	39.24	39.24	39.24
Soybean meal,44% (IFN 5-04-612)	27.43	27.43	27.43	31.00	31.00	31.00
Dried whey (IFN 4-01-182)	20.00	20.00	20.00	20.00	20.00	20.00
Wheat starch	3.0	1.5	0	3.0	1.5	0
Soy lecithin[a]	0	1.5	3.0	0	1.5	3.0
Choice white grease	0	0	0	4.0	4.0	4.0
L-lysine HCl	.21	.21	.21	.23	.23	.23
Dical (IFN 6-01-080)	1.23	1.23	1.23	1.00	1.00	1.00
Limestone (IFN 6-02-632)	.67	.67	.67	.73	.73	.73
Salt (IFN 6-02-632)	.10	.10	.10	.10	.10	.10
Trace mineral premix[b]	.10	.10	.10	.10	.10	.10
Vitamin premix[c]	.25	.25	.25	.25	.25	.25
Selenium premix[d]	.10	.10	.10	.10	.10	.10
ASP-250	.25	.25	.25	.25	.25	.25
	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrient values						
% Protein	18.6	18.6	18.6	19.5	19.5	19.5
% Lysine	1.25	1.25	1.25	1.35	1.35	1.35
% Ca	.80	.80	.80	.80	.80	.80
% P	.70	.70	.70	.70	.70	.70
g protein:g lysine	14.88:1	14.88:1	14.88:1	14.44:1	14.44:1	14.44:1
Kcal ME:g protein[e]	17.2	17.4	17.6	17.2	17.5	17.7

[a]Merrick Foods, Union Center, WI.

[b]Provided the following in the complete diet (ppm): Mn, 50; Zn, 100; Fe, 100; Cu, 10; I, 3 and Co 1.

[c]Provided the following per kg of complete diet: vitamin A, 8,800 IU; vitamin D_3, 660 IU; vitamin E, 44 IU; riboflavin, 9.9 mg; d-pantothenic acid, 26.4 mg; niacin, 55 mg; vitamin B_{12}, 48.4 µg; choline chloride, 1014.2 mg and menadione, 3.4 mg.

[d] Provided 200 µg Se per kg complete diet.

[e]Lecithin, 6.7 Mcal/kg (Renner and Hill, 1958); choice white grease, 7.7 Mcal/kg; wheat starch, 4.0 Mcal/kg.

Table 6. Diet Composition for Trial 3 and Digestion Trial

Ingredient,%	589A	589B	589C	589D
Corn (IFN 4-02-935)	43.90	43.90	43.90	43.90
Soybean meal,44% (IFN 5-04-612)	29.02	29.02	29.02	29.02
Dried whey (IFN 4-01-182)	20.00	20.00	20.00	20.00
Wheat starch	4.0	0	0	0
Choice white grease	0	4.0	0	2.0
Soy oil[a]	0	0	4.0	2.0
Dical (IFN 6-01-080)	1.13	1.13	1.13	1.13
Limestone (IFN 6-02-632)	.82	.82	.82	.82
Salt (IFN 6-02-632)	.10	.10	.10	.10
L-lysine HCl	.33	.33	.33	.33
Trace mineral premix[b]	.10	.10	.10	.10
Vitamin premix[c]	.25	.25	.25	.25
Selenium premix[d]	.10	.10	.10	.10
ASP-250	.25	.25	.25	.25
	100.00	100.00	100.00	100.00
Analyzed nutrient values				
% Protein	20.43	20.43	19.53	19.40
% Fat	1.99	5.74	6.10	6.20
% Lysine	1.39	1.28	1.42	1.30
% Ca	.94	.88	.88	.80
% P	.69	.69	.65	.67
Cal GE/gram[e]	3898.03	4151.28	4159.69	4091.91

[a]Bunge Corp., Emporia, KS.

[b]Provided the following in the complete diet (ppm): Mn, 50; Zn, 100; Fe, 100; Cu, 10; I, 3 and Co, 1.

[c]Provided the following per kg complete diet: vitamin A, 8,800 USP; vitamin D_3, 660 USP; vitamin E, 44 IU; riboflavin, 9.9 mg; menadione, 3.4 mg; d-pantothenic acid, 26.4 mg; niacin, 55 mg; choline chloride, 1014.2 mg; vitamin B_{12}, 48.4 µg.

[d]Provided 200 µg Se per kg complete diet.

[e]Analyzed by oxygen bomb calorimetry according to A.O.A.C. (1980) methods.

Results and Discussion

Trial 1. The effects on pig performance of adding lecithin to starter diets with or without supplemental fat are shown in table 7. The addition of 4% choice white grease to a diet without spray-dried whey decreased feed intake and improved feed efficiency ($P<.05$). However, there was no significant change in ADG. Addition of lecithin at 1.5 or 3.0% to the fat-supplemented diets showed no improvement in pig performance compared to the control diet, nor was there any lecithin x fat interaction. Lecithin addition at 1.5% in the diet without added fat gave a response similar to those diets with 4% added fat. Six pigs died during the trial and necropsy reports proved inconclusive as to cause of death.

Trial 2. The effects on pig performance of adding lecithin and(or) supplemental fat to starter diets containing 20% spray-dried whey are shown in table 8. In diets containing 20% dried whey, the addition of 4% choice white grease decreased feed intake and improved feed efficiency ($P<.05$). Average daily gain remained unchanged and no significant response to the addition of lecithin was observed. There was a significant ($P<.05$) lecithin x fat interaction which affected ADG (figure 1). In diets without lecithin ADG increased with the addition of fat but decreased when 1.5 or 3.0% lecithin was added. The treatment having 4% fat and 3% lecithin had the lowest ADG. Eight pigs died during the trial and necropsy reports proved inconclusive as to cause of death.

Trial 3. The performance of pigs fed diets supplemented with 4% choice white grease (CWG), 4% soy oil (SO) or a 2% CWG+2% SO mixture is shown in table 9. There was no effect on feed intake due to treatment. However, there was a significant block effect with the pigs in block 1 (lightweight) consuming significantly less feed than the pigs in blocks 2 or 3. There was a similar block effect on ADG. Overall, the pigs in block 1 gained less than those in blocks 2 or 3 ($P<.05$). There was no difference in ADG between fat sources, however the pigs fed the soy oil-supplemented diet gained significantly more than the pigs receiving the control diet. The pigs in block 1 that received the SO-supplemented diet gained an average of .39 kg/day throughout the trial. Block 1 pigs on the SO treatment gained faster than the pigs fed the control and CWG-supplemented diets. Feed efficiency was significantly improved with the addition of 4% fat, regardless of source ($P<.05$).

Trial 4. Results of the digestion trial for diets supplemented with choice white grease (CWG), soy oil (SO) or a mixture of 2% CWG+2% SO (MIX) are shown in (table 10). The addition of fat to the control diet significantly improved ether extract digestibility, with the MIX being superior to the CWG or SO diets ($P<.05$). Dry matter, crude protein and energy digestibilities tended to show a depression with the addition of fat. However, only the SO-supplemented diet was significantly inferior to the control diet. Nitrogen retention was maximized on the diet supplemented with 4% CWG, although this was not significantly different from the control diet. There was a slight numerical depression in N-retention for the diet supplemented with a MIX. N-retention was significantly depressed with the addition of 4% SO.

Table 7. Effect of Lecithin Addition to Starter Pig Diets (Trial 1).

Item	% Fat	% Lecithin			Mean	SE
		0	1.5	3.0		
Avg daily feed intake (kg)						
	0	.59	.54	.59	.57[a]	.050
	4	.53	.44	.48	.48[b]	
	Mean	.56	.49	.53		.062
Avg daily gain (kg)						
	0	.43	.42	.44	.43	.031
	4	.43	.37	.37	.39	
	Mean	.43	.40	.41		.038
Feed efficiency						
	0	1.38	1.27	1.34	1.33[a]	.029
	4	1.23	1.19	1.28	1.23[b]	
	Mean	1.31	1.23	1.31		.036

[ab]Dietary fat effect ($P<.05$).

Table 8. Effect of Lecithin Addition to Starter Pig Diets with 20% Dried Whey (Trial 2).

Item	% Fat	% Lecithin 0	1.5	3.0	Mean	SE
Avg daily feed intake (kg)						
	0	.70	.71	.74	.72[a]	.038
	4	.67	.65	.66	.66[b]	
	Mean	.69	.68	.70		.046
Avg daily gain (kg)[c]						
	0	.46	.47	.48	.47	.016
	4	.51	.48	.45	.48	
	Mean	.49	.48	.47		.020
Feed efficiency						
	0	1.52	1.50	1.54	1.52[a]	.026
	4	1.32	1.36	1.45	1.37[b]	
	Mean	1.42	1.43	1.50		.031

[ab]Dietary fat effect ($P<.05$).

[c] Lecithin x fat interaction ($P<.05$).

FIGURE 1. EFFECT OF FAT AND LECITHIN ON AVG DAILY GAIN

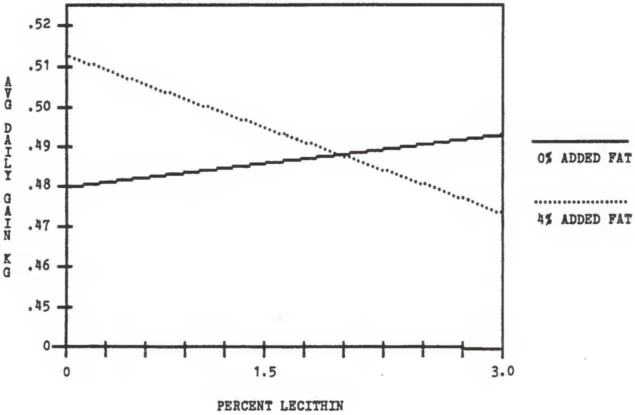

Table 9. Effect of the Addition of Various Fat Sources to Starter Pig Diets[a] (Trial 3).

Item	Block	Diet[b]				SE
		Control	CWG	SO	CWG+SO	
Avg daily feed intake (kg)[c]						
	1	.44[de]	.36[d]	.55[e]	.50[e]	.054
	2	.56	.55	.46	.52	.044
	3	.61	.57	.53	.56	.054
	Overall	.54	.49	.51	.52	.059
Avg daily gain (kg)[c]						
	1	.33[d]	.32[d]	.39[e]	.36[de]	.018
	2	.38	.40	.37	.37	.015
	3	.39	.39	.42	.42	.018
	Overall	.36[d]	.37[de]	.39[e]	.38[de]	.019
Feed efficiency						
	1	1.34[de]	1.11[d]	1.41[e]	1.39[e]	.045
	2	1.46	1.39	1.25	1.40	.036
	3	1.55	1.45	1.26	1.33	.045
	Overall	1.45[d]	1.32[e]	1.31[e]	1.37[e]	.048

[a]1=3.7 kg initial weight, 2=4.9 kg initial weight, 3=5.9 kg initial weight.

[b]Control=corn-soy fortified basal diet, CWG=control + 4% choice white grease, SO=control + 4% soybean oil, CWG+SO=control + 2% choice white grease + 2% soybean oil.

[c]Block effect (P<.05).

[de]Means on same line with different superscripts differ (P<.05).

Table 10. Apparent Digestibilities of Diets Containing Various Fat Sources (Trial 4)[a].

Item	Diet[b]				SE
	Control	CWG	SO	CWG+SO	
Dry matter digestibility,%	88.0[c]	87.0[c]	85.8[d]	87.2[c]	.42
Protein digestibility,%	85.4[c]	84.2[c]	82.2[d]	84.0[cd]	.69
Ether extract digestibility,%	52.1[c]	77.3[d]	77.2[d]	82.5[e]	1.64
Energy digestibility,%	87.6[c]	86.8[c]	85.7[d]	87.4[c]	.36
Nitrogen retention	29.2[c]	30.0[c]	26.4[d]	28.0[cd]	.83

[a]Initial pig weight 5.45 kg.

[b]Control = corn soy fortified basal diet, CWG = control + 4% choice white grease, SO = control + 4% soy oil, CWG+SO= control + 2% choice white grease + 2% soy oil.

[cde]Means in same row with different superscripts differ ($P<.05$).

[f]Nitrogen retention = nitrogen intake - (nitrogen in urine + nitrogen in feces).

Discussion

Trial 1. The addition of 4% choice white grease (CWG) to a pig starter diet in which a constant calorie-protein ratio was maintained showed a decrease in feed intake and an improvement in feed efficiency. Several earlier studies showed similar results (Kennington et al., 1958; Frobish et al., 1967, 1969, 1970; Lawrence and Maxwell, 1983). Average daily gain was not affected since the pigs were still consuming approximately the same amounts of energy. Asplund et al. (1960), Allee and Hines (1970b) and Brooks (1972) also reported no significant effect on rate of gain when the calorie-protein ratio was constant.

The addition of lecithin at 1.5 or 3.0% of the diet did not affect feed intake, rate of gain or feed efficiency in either the fat supplemented or the unsupplemented diets. There was no fat x lecithin interaction. Previous studies involving lecithin addition to the diets of young pigs have also reported no significant improvements in fat utilization or ADG (Sheffy et al., 1951; Hanson et al., 1954; Frobish et al., 1969). These studies all utilized very low levels of lecithin and it may be possible that it was not sufficient to exhibit any effect on fat utilization. Studies in poultry have shown the level of lecithin to be very critical. The addition of unbleached soy lecithin to tallow-supplemented (10%) chick diets at 1 or 3% of the diet did not appear to change availability of the fat (Sibbald et al., 1962). However, when lecithin was added at the 2% level the metabolizable energy (ME) value of the tallow was increased by almost one kcal. Polin (1980) also reported increased absorption of tallow with the addition of 2% soy lecithin to chick diets.

A low level (1.5%) of soy lecithin in the diet gave a response similar to those diets with 4% added fat. This would support the theory of the improved utilization of lecithin as compared to other fat sources, in this case choice white grease. Renner and Hill (1958) reported a ME value of 6732 kcal/kg for soy lecithin, which would be approximately 87% the ME value of choice white grease (7700 kcal ME/kg). From the feed efficiencies obtained in trials 1 and 2, lecithin had a range of 84-95% the caloric value of the choice white grease used. Feed intake and efficiency were depressed with 3% added soy lecithin, again indicating the level of lecithin to which a benefical response is seen to be critical (Sibbald et al., 1962; Polin, 1980).

Trial 2. The addition of 4% CWG to a pig starter diet, which contained 20% spray-dried whey, caused a decrease in feed intake and an improvement in feed efficiency. Since pigs eat to meet their energy needs, a decrease in feed intake would be expected when feeding a fat-supplemented diet. Stahly et al. (1983) also reported enhanced performance in weanling pigs when 10% spray-dried whey was added to a fat-supplemented diet. The addition of fat to a corn-SBM diet did not enhance the initial 28-day postweaning performance. However, the inclusion of dried whey improved the postweaning survival rate and efficiency of growth of the 28-day old weanling pigs. When a constant calorie-protein ratio was maintained, the inclusion of fat in the corn-SBM-whey diet enhanced ADG and metabolizable energy per unit gain in pigs. Their data suggest that the ability of weanling pigs to utilize dietary fat is enhanced by the presence of spray-dried whey in the diet. The lipase and(or) lecithin naturally present in whey may be partially responsible for the enhanced utilization of fat in the whey-supplemented diets. Also, since fat additions to a whey-supplemented diet only improved efficiency in diets in which a constant calorie-lysine ratio was maintained, it was suggested that a minimum calorie-lysine ratio may be necessary for the nutritional value of added dietary fat to be expressed. Frobish et al. (1970) reported enhanced fat utilization in starter diets containing milk protein as compared to diets utilizing soybeans as a protein source. Pigs fed casein diets gained more (8.22 vs. 6.49, $P<.01$) and weremore efficient than pigs fed isolated soy protein diets. The digestibility coefficients for fat were higher for the casein diets than for the soy protein diets. They concluded that milk proteins were superior to soybean proteins in baby pig diets and suggested that protein source may influence the utilization of fat.

The addition of soy lecithin at 1.5 or 3.0% did not significantly affect pig performance. Previous studies on the addition of soy lecithin to starter pig diets have also reported no significant improvements in fat utilization or ADG (Sheffy et al., 1951;

Hanson et al., 1954). Frobish et al. (1969) did report a small improvement in fat digestibility with the addition of 1% soy lecithin in 25-day old pigs, although this was not significant (74.39 vs. 77.90%).

There was a fat x lecithin interaction (P<.05) which affected ADG. In diets without lecithin, ADG increased with the addition of fat but decreased when 1.5 or 3.0% lecithin was added. The treatment having 4% fat and 3% lecithin had the lowest ADG This may be due to a high level of undigestible fat having a limiting effect on intake and consequently decreasing gains. Frobish et al. (1967, 1969, 1971), Liebbrandt et al. (1975), and Lawrence and Maxwell (1983) reported a quadratic effect on daily gain with increasing levels of fat. There was a marked improvement in gain when fat level increased from 0 to 5%, but there was a slight decrease in gain going from 5 to 10% added fat. Increasing the fat content from 5 to 10% also increased the energy requirement 6% per unit gain (Frobish et al., 1970). Lawrence and Maxwell (1983) also observed a decrease in daily gain on a 12% added fat diet when compared to 4 or 8% over a five-week period. Adding a high level of fat appeared to be detrimental in the first two weeks postweaning, as the pigs on the 12% fat-supplemented diet lost weight during this time. The efficiency of digestible energy utilization was improved with the lower levels of fat, with 4% added fat being superior.

Trial 3. There was a numerical decrease in feed intake and increase in ADG with the addition of 4% choice white grease, 4% soy oil or a 2% CWG+2% SO combination. However, feed efficiency was improved (P<.05) over that of the control by the addition of 4% CWG or 4% SO. An improvement in feed efficiency is common with the addition of fat and has been reported by several researchers (Kennington et al., 1958; Frobish et al., 1967, 1969, 1971; Lawrence and Maxwell, 1983).

There was no difference in ADG between fat sources, with the exception of pigs fed the soy oil-supplemented diet. Overall, the pigs receiving soy oil gained significantly more when compared to the controls. The light weight pigs, less than 3.7 kg initially, receiving soy oil gained more than the control pigs or those receiving the CWG-supplemented diet (P<.05). There was also a numerical improvement over the pigs receiving the CWG-SO supplemented diet. This improvement is partially due to the poorer performance of the pigs receiving the CWG-supplemented diet. Two pigs from this group died and two had extremely poor gains, weighing less than 12.7 kg at 9 weeks of age, which would have significantly affected the overall pen average. Asplund et al. (1960) observed that pigs fed choice white grease did not gain more than those fed no added fat. Results obtained when feeding soy oil have been conflicting. Freeman et al. (1968) and Braude and Newport (1973) observed pigs fed soy oil-supplemented diets had enhanced performance when compared to more saturated fat sources such as tallow or lard. Pigs have been reported to require linoleic and linolenic acid in their diets (Church, 1979). From the analyzed fatty acid profiles of the SO and CWG used, it can be seen that the SO is over 50% linoleic acid. Hamilton and McDonald (1969) reported poor utilization of palmitic and stearic acids in the young pig, which account for over 35% of the composition of the CWG used. Similar observations have been reported in the chick (Renner and Hill, 1961) and rat (Mattil and Higgins, 1946). This may provide a possible explanation as to why the lightweight pigs fed SO would perform slightly better than those fed CWG-supplemented diets. However, Eusebio et al. (1965) reported impaired performance for pigs fed soybean oil. Two-wk old pigs fed a diet with 5 or 10% added soybean oil gained significantly less than those pigs fed a diet with no added fat. In a second trial, the source of fat (lard, tallow, soybean oil) had no effect on feed conversion or apparent digestibility. Overall, they concluded that the young pig is relatively inefficient in utilizing soybean oil. Bate et al. (1946) and Jacobson et al. (1949) reported similar observations in calves fed soybean oil. When soybean oil replaced butterfat in a milk diet neither growth nor general appearance was enhanced.

Trial 4. The addition of 4% CWG, 4% SO or a combination of 2% CWG+2% SO (MIX) decreased digestibility of dry matter, crude protein and energy digestibilities. These results are conflicting with those reported in earlier literature. Greeley et al. (1964) observed an improvement in the efficiency of dry matter utilization with the addition of increasing levels of tallow. Fat levels ranged from 4 to 12%. Lowry et al. (1958) also showed numerical improvements in dry matter digestibility with the addition of 10% fat to a 13 or 16% crude protein diet. The differences were not significant, however, and there was no advantage to adding fat (source not cited by researchers) to a 19% crude protein diet. Energy digestibilities have also been reported to increase with the addition of fat. Pigs on fat-supplemented diets had significantly higher energy and crude protein digestibility than those on diets without added fat (Tribble et al., 1979). Kuryvial et al. (1962) reported improved energy and protein utilization for pigs fed 15 or 30% added fat throughout the growing period as compared to those with no added fat. In a paper comparing starter diets supplemented with 11 or 16% stabilized white grease or 16% corn oil, there was an increase in the apparent digestibility of crude protein (Asplund et al., 1960).

The addition of fat to the control diet significantly improved ether extract digestibility, with the MIX being superior to the CWG or SO-supplemented rations. Several studies have shown the inclusion of fat to a swine ration to improve the percent ether extract utilized (Asplund et al., 1960, Frobish et al., 1967, 1969). Liebbrandt et al. (1975) reported increased ether extract digestibility for baby pigs when going from 5 to 10% added lard. Ether extract digestibility was decreased in pigs fed a hydrolyzed fat-supplemented diet. The researchers also reported age to have a significant effect on ether extract digestibility, as it improved as the pigs got older.

Pigs fed the SO-supplemented diets had lower digestibility coefficients when compared to those fed the other fat sources, which appears to conflict with the performance data from trial 3. It should be noted that the greatest improvements in performance to SO in trial 3 were seen with the lightweight pigs. Pigs used in the digestion trial would more closely correspond with those in the heavy weight block, in which there were no signficant improvements with SO as compared to CWG.

Summary

Three growth trials and a digestion trial were conducted to study the effects of the use of an emulsifier and differences in saturation among fat sources on nutrient utilization in the weanling pig. In a 35-d growth trial, 120 crossbred pigs averaging 22 days of age and 6.0 kg, were used to determine the level and effects of soy lecithin addition to starter diets with or without added fat. Choice white grease was the fat source. Three levels of lecithin, 0, 1.5 and 3.0% and two levels of fat, 0 and 4%, were used (2x3 factorial design). The addition of 4% choice white grease to the diet decreased feed intake and improved feed efficiency ($P<.05$) and there was no significant change in ADG. Addition of lecithin at 1.5 or 3.0% to the fat-supplemented diets showed no improvement in pig performance compared to the control, nor was there any fat x lecithin interaction. A low level of lecithin in the diet without fat gave a response similar to those diets with 4% added fat.

In trial 2, 210 crossbred pigs averaging 22 days of age and 6.6 kg were used to determine the effects of soy lecithin addition to a starter pig diet containing 20% spray-dried whey. Treatments were identical to those of trial 1, except all diets contained spray-dried whey. The addition of 4% choice white grease decreased feed intake and improved feed efficiency ($P<.05$) as in trial 1. Average daily gain remained unchanged and no significant response to the addition of soy lecithin was observed. A significant fat x lecithin interaction was observed for ADG. In diets without lecithin, ADG increased with the addition of fat but decreased when 1.5 or 3.0% lecithin was added. The treatment having 4% fat and 3% lecithin had the lowest ADG.

A third growth trial was conducted to evaluate the addition of a saturated, unsaturated, or mixed source of fat on pig performance. All diets contained 20% spray-dried whey. One hundred sixty-eight crossbred pigs, averaging 22 days of age were used. The pigs were blocked on weight and randomly assigned to one of 4 dietary treatments; a corn-soy fortified control, control + 4% choice white grease (CWG), control + 4% soy oil (SO), control + 2% CWG + 2% SO. There was no effect on feed intake due

to treatment. The lightweight pigs on the SO diet gained more than the pigs in the same weight block on the control or CWG diets. There was no difference in ADG between fat sources excepting the pigs fed the SO diet gained significantly more than the control pigs. Feed efficiency was improved ($P<.05$) with the addition of 4% fat, regardless of fat source.

A digestion trial was conducted to determine the dry matter, crude protein, ether extract and energy digestibility in the weanling pig when CWG, SO or a combination thereof, was added to a corn-soy basal diet. Twelve crossbred barrows, averaging 5.45 kg were used. Pigs were randomly allotted to treatments and allowed a 5-d adjustment prior to a 5-d collection period. Treatments were then reallotted and pigs were allowed a 5-d adjustment period prior to a second 5-d collection period. Intake was 100 g feed and 250 ml water fed twice daily for the first period and 190 g and 450 ml water fed twice daily for the second period. Diets were identical to those in the third growth trial. The addition of fat to the control diet significantly improved ether extract digestibility with the CWG+SO being superior to CWG or SO alone. Dry matter, crude protein and energy digestibility tended to show a depression with the addition of fat; however, only the SO diet was significantly inferior to the CWG+SO diet. N-retention was maximized on the CWG diet, although this was not significantly different from the control. There was a slight numerical depression in N-retention for the CWG+SO diet. N-retention was significantly depressed with the addition of 4% SO.

From the research reported herein it was found that the addition of unbleached soy lecithin did not enhance pig performance nor did it appear to affect feed or fat utilization. There were no benefits nor additive effects observed when combining choice white grease with an unsaturated fat source, such as lecithin or soy oil, as compared to choice white grease alone.

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APPENDIX

Table 1. Analyzed Diet Composition for Trial 1[a]

Analyzed nutrient values	586A	586B	586C	586D	586E	586F
% Protein	19.40	19.66	19.92	20.82	20.95	20.82
% Fat	3.11	4.33	5.78	6.47	7.58	9.11
% Crude fiber	3.30	3.20	3.30	3.30	3.20	3.20
% Ash	5.83	5.85	6.00	5.95	5.80	6.08
% Moisture	12.29	11.95	11.75	11.81	11.43	11.28
% Calcium	1.00	1.05	1.06	1.09	1.05	1.08
% Phosphorus	.69	.71	.73	.68	.72	.74
% Lysine	1.08	1.15	1.02	1.03	1.07	1.10

[a]Analysis conducted by Woodson-Tenant Laboratories, Des Moines, IA.

Table 2. Analyzed Diet Composition for Trial 2[a]

Analyzed nutrient values	588A	588B	588C	588D	588E	588F
% Protein	19.02	18.89	18.50	20.05	19.92	20.82
%Fat	2.03	3.32	4.75	5.30	7.07	7.71
% Crude fiber	3.00	2.90	2.90	3.20	3.20	3.00
% Ash	6.35	6.55	6.70	6.15	6.43	6.50
% Moisture	11.64	12.11	11.63	11.45	11.39	11.45
% Calcium	.78	.81	.78	.74	.73	.74
% Phosphorus	.66	.75	.74	.66	.62	.71
% Lysine	1.07	1.12	1.00	1.07	1.16	1.23

[a]Analysis conducted by Woodson-Tenant Laboratories, Des Moines, IA.

EFFECT OF LECITHIN AND SOURCE AND LEVEL OF FAT IN STARTER PIG DIETS ON PERFORMANCE AND NUTRIENT UTILIZATION

by

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B.S., University of Illinois, 1983

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1985

Abstract

Three growth trials and a digestion trial were conducted to study the effects of the use of an emulsifier and differences in saturation among fat sources on nutrient utilization in the weanling pig. In a 35-d growth trial, 120 crossbred pigs averaging 22 days of age and 6.0 kg, were used to determine the level and effects of soy lecithin addition to starter diets with or without added fat. Choice white grease was the fat source. Three levels of lecithin, 0, 1.5 and 3.0% and two levels of fat, 0 and 4%, were used (2x3 factorial design). The addition of 4% choice white grease to the diet decreased feed intake and improved feed efficiency ($P<.05$) and there was no significant change in ADG. Addition of lecithin at 1.5 or 3.0% to the fat-supplemented diets showed no improvement in pig performance compared to the control, nor was there any fat x lecithin interaction. A low level of lecithin in the diet without fat gave a response similar to those diets with 4% added fat.

In trial 2, 210 crossbred pigs averaging 22 days of age and 6.6 kg were used to determine the effects of soy lecithin addition to a starter pig diet containing 20% spray-dried whey. Treatments were identical to those of trial 1, except all diets contained spray-dried whey. The addition of 4% choice white grease decreased feed intake and improved feed efficiency ($P<.05$) as in trial 1. Average daily gain remained unchanged and no significant response to the addition of soy lecithin was observed. A significant fat x lecithin interaction was observed for ADG. In diets without lecithin, ADG increased with the addition of fat but decreased when 1.5 or 3.0% lecithin was added. The treatment having 4% fat and 3% lecithin had the lowest ADG.

A third growth trial was conducted to evaluate the addition of a saturated, unsaturated, or mixed source of fat on pig performance. All diets contained 20% spray-dried whey. One hundred sixty-eight crossbred pigs, averaging 22 days of age were used. The pigs were blocked on weight and randomly assigned to one of 4 dietary treatments; a corn-soy fortified control, control + 4% choice white grease (CWG), control + 4% soy oil (SO), control + 2% CWG + 2% SO. There was no effect on feed intake due

to treatment. The lightweight pigs on the SO diet gained more than the pigs in the same weight block on the control or CWG diets. There was no difference in ADG between fat sources excepting the pigs fed the SO diet gained significantly more than the control pigs. Feed efficiency was improved ($P<.05$) with the addition of 4% fat, regardless of fat source.

A digestion trial was conducted to determine the dry matter, crude protein, ether extract and energy digestibility in the weanling pig when CWG, SO or a combination thereof, was added to a corn-soy basal diet. Twelve crossbred barrows, averaging 5.45 kg were used. Pigs were randomly allotted to treatments and allowed a 5-d adjustment prior to a 5-d collection period. Treatments were then reallotted and pigs were allowed a 5-d adjustment period prior to a second 5-d collection period. Intake was 100 g feed and 250 ml water fed twice daily for the first period and 190 g and 450 ml water fed twice daily for the second period. Diets were identical to those in the third growth trial. The addition of fat to the control diet significantly improved ether extract digestibility with the CWG+SO being superior to CWG or SO alone. Dry matter, crude protein and energy digestibility tended to show a depression with the addition of fat; however, only the SO diet was significantly inferior to the CWG+SO diet. N-retention was maximized on the CWG diet, although this was not significantly different from the control. There was a slight numerical depression in N-retention for the CWG+SO diet. N-retention was significantly depressed with the addition of 4% SO.

From the research reported herein it was found that the addition of unbleached soy lecithin did not enhance pig performance nor did it appear to affect feed or fat utilization. There were no benefits nor additive effects observed when combining choice white grease with an unsaturated fat source, such as lecithin or soy oil, as compared to choice white grease alone.