FAT UTILIZATION BY THE EARLY WEANED PIG

By

BRENDA DE RODAS

Bachelor of Science

National University of Honduras

Tegucigalpa, Honduras

1982

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1989

FAT UTILIZATION BY THE EARLY WEANED PIG

Thesis Approved:

Charles V. Maxwell
Thesis Advisor

Robert Teeter

David S Buchanan

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to thank the Oklahoma State University Animal Science Department for allowing me the opportunity to continue my education. Special thanks are extended to my major professor, Dr. C.V. Maxwell, for his guidance and encouragement during my program.

I would also like to thank members of my committee, Dr. R. Teeter and Dr. D.S. Buchanan and fellow graduate students for their assistance.

I especially thank my husband, Horacio, for his hard work and support as well as my son, Horacio Enrique, for their patience during this time as a graduate student at Oklahoma State University.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Weaning pigs as early as three weeks of age is often economically advantageous to swine producers. This practice will shorten the reproductive cycle of the sow herd and allow placement of females back into productivity sooner with the expectation of rearing more pigs per sow per year and thus maximizing profit.

However one of the major problems with early weaning is "postweaning lag" in the early-weaned pig, a condition which lasts from five to ten days, and is characterized by a reduction of feed intake, decreased gains or weight loss, and often diarrhea. Early-weaned pigs also commonly experience a longer postweaning growth depression and a higher incidence of mortality as compared to those weaned at an older age. This reduction in performance has been attributed to the drastic change in diet as well as environment. Since sow's milk, which contains 30 to 40% fat on a dry matter basis, is efficiently utilized by the young pig, one solution to post-weaning lag could be supplementation of early-weaned pig diets with very high quality fat.

Several studies have been conducted to evaluate the performance of early weaned pigs fed fat-supplemented diets. The results of these studies often conflict, possibly due to several factors, namely differences in the age of the pigs at the start of the experiment, differences in the nutrient-to-energy ratio of the diet or differences in the level and type of fat supplement. Concerning to this latter factor, many researchers (Brawde and Newport, 1973; Cera et al., 1988; Hamilton and MacDonald, 1968; Lawrence and Maxwell, 1983; Lloyd and Crampton, 1957; Sewell and Miller, 1965) have indicated that the source of fat does influence the ability of the young pig to utilize fat and that the differences observed in performance could be associated with the fatty acid composition of the fats. Some of these studies suggested that sources of fat high in short- and medium-chain fatty acids are most effectively utilized by the young pig.

Recently, medium-chain triglycerides have been manufactured and may offer an alternative fat source for early-weaned pigs. Medium-chain triglycerides are esters of glycerol and saturated fatty acids containing between six and twelve carbon atoms, although C8:0 and C10:0 fatty acids are the major components of most medium chain triglyceride preparations. It is well documented that medium chain triglycerides are readily hydrolyzed and absorbed from the digestive tract and transported to the liver via the portal venous system where they are largely oxidized. Medium-chain triglycerides unlike long-chain triglycerides, are absorbed mainly as free fatty acids, and only rarely as monodiacylglycerols. Since medium-chain triglycerides can be digested in the absence of bile salts or pancreatic lipase, a large fraction of medium-chain triglycerides can be absorbed even by early-weaned pigs where lipase activity decreases after weaning (Schere et al., 1973 and Hartman et al., 1961).

Since medium-chain triglycerides are sources of abundant and rapidly available energy, they have been evaluated as a possible alternative for improving the energy status and survival of neonatal pigs (Lepine et al., 1989 and Odle et al., 1988). However, the effect of medium-chain triglycerides on the performance of the early-weaned pig (18 to 21 days) has not yet been evaluated.

Numerous experiments have been conducted to evaluated the performance of early-weaned pigs fed animal fat-supplemented diet (Aherne et al., 1983; Allee et al., 1971; Brawde and Newport, 1975; Eucebio et al., 1965; Lawrence and Maxwell, 1983; Cera et al., 1988); however, data to date have fail to document whether the young pig is capable of utilizing tallow as effectively as lard.

This study was conducted to assess the effect of fat source on the performance of early-weaned pigs. Four fat sources differing in fatty acid composition were studied. The specific objectives of this study were: 1) to compare the effect of diets containing lard or butterfat on gain and efficiency of gain in early weaned pigs; 2) to determine the effect of replacing a portion of lard with medium-chain triglycerides (captex 300 medium chain triglycerides) on the performance of early weaned pigs; and 3) to obtain preliminary data on the effect on performance in early-weaned pigs of replacing a portion of the lard with tallow.

CHAPTER II

REVIEW OF LITERATURE

Numerous experiments have been conducted to study the effects of fat in the diet on growth rate and feed conversion efficiency in early-weaned pigs. The results of these studies often conflict, possibly due to several factors, namely differences in the age of the pig at the start of the experiment, differences in the nutrient-to-energy ratio of the diet, or differences in the level and type of fat added (Aherne et al., 1982). The first two factors have been discussed by Lawrence and Maxwell (1983), Allee et al. (1971), Allee and Hines (1972), and Aherne et al. (1982). Concerning the latter factor, researchers have observed considerable variation in the absorbability and utilization of various types of dietary fats. Differences in fatty acid composition appears to be one of the major sources of variability in the effect of fat on performance (Lloyd et al., 1957; Hamilton and Macdonald, 1969; Lawrence and Maxwell, 1983; Brawde and Newport, 1973; Cera et al., 1988, Brawde and Newport, 1973).

Studies have shown that medium-chain and unsaturated fatty acids are better hydrolyzed (Lloyd and Crampton, 1957; Sewell and Miller, 1965; Hamilton and Mcdonald, 1969 and

Ozimek et al., 1984) and oxidized (Miller et al., 1971; Duee et al., 1985; Lepine et al., 1987 and Boyd et al., 1982) by the young pig when compared to long chain saturated fatty acids. For example stearic acid, a long-chain saturated fatty acid, appears to be the most poorly utilized fatty acid by the young pig.

The Effect of Fat Source on Fat Utilization

The ability of the young pig to utilize a diet high in fat may be partially dependant upon the type of fat included in the diet. Brawde and Newport (1973) studied the effects of replacing butterfat in a whole milk diet with either beef tallow, coconut oil, or soybean oil. The pigs were weaned to the liquid diet at two days of age and the trial lasted twenty six days. The performance of the pigs and the apparent digestibility of the dietary fats indicated that soybean oil was equal to butterfat and that butterfat was slightly superior to coconut oil and markedly superior to beef tallow. The total fatty acid content of the proximal- and mid-region of the small intestine was unaffected by the type of fat in the diet. However, with the tallow diet, the distal portion had an increased fatty acid content, a factor which suggested poorer utilization of this fat. Aherne et al. (1982) reported that the addition of 10% lard to an adjusted (protein-to-energy ratio was held constant) starter diet improved average daily gain and feed conversion efficiency. Likewise, Leibbrant et al. (1975) reported that feed efficiency was improved with the addition of lard to the early-weaned pig diet.

Wolfe et al. (1977) studied the effect of level of butterfat in a liquid diet on the performance of pigs from zero to fourteen days of age. The three diets contained 2%, 17% and 32% fat on a dry matter basis. An increase in the level of dietary fat resulted in a significant increase in 14-day weight gain and a tendency for improved feed efficiency. These results demonstrate not only that the young pig can utilize semipurified liquid diets high in butterfat, but also that energy from butterfat appears to be used as efficiently as energy from glucose for growth purposes.

In a study by Lawrence and Maxwell (1983) neonatal pigs were fed liquid semipurified diets from 0 to 20 days of age to determine the effect of four dietary fat sources on performance. The four diets contained 32% butterfat, corn oil, coconut oil, or lard on a dry matter basis. Gain and efficiency of feed use were greater ($P<.05$) for pigs fed coconut oil than for pigs fed corn oil or lard. Pigs fed a butterfat-supplemented diet performed better than pigs fed a lard, and corn oil-supplemented diet, but the differences were not significant.

The utilization of various dietary fats by early-weaned pigs was studied by Thaler et al. (1988) in two 5-week trials. Treatment consisted of a control with no added fat, and fat additions of either soybean oil (SOY), coconut oil

(COCO), choice white grease (CWG), 1/2 soy: 1/2 coco (SOCO), or 1/2 CWG: 1/2 COCO (CWCO). Diets were supplemented with 10% fat for the first two weeks of the study and 5% fat for the next three weeks. Daily feed intake was decreased for the first two weeks when fat was added ($P<.01$), but ADG and F:G were unaffected by dietary treatment. For the overall 5-week study, fat additions improved ADG ($P<.06$) and F:G ($P<.01$). Comparing the experimental groups, pigs fed SOCO diets consumed more feed than pigs fed either the COCO or CWG diets ($P<.05$), and gained faster than pigs fed the COCO diet ($P<.05$).

Cera et al. (1988) in a 28 day trial reported that the apparent digestibility of the total fat of 28-day old pigs was higher for pigs fed corn oil-supplemented diets when compared to those fed either tallow- or lard-supplemented diets during each week postweaning ($P<.05$). The apparent digestibilities of fat within each weekly period were similar for the tallow- and lard-supplemented diets. Additionally, the apparent digestibility of fat increased ($P<.01$) for each fat source for each week postweaning but appeared to reach a plateau by the third week postweaning.

In a second trial conducted by Cera et al. (1988) source of fat (corn oil, lard, and tallow) had no effect on the weekly or the overall 28-day growth rate or on the feed-to gain ratio. These experiments indicated that apparent fat digestibilities and dietary fat absorption increased with either postweaning age or time. Supplemental corn oil resulted in a higher apparent digestibility and absorption of fat and dry matter digestibility, especially during the initial 2-week postweaning period; however corn oil did not increase gains or feed utilization relative to lard-or tallow-supplemented diets. These results are consistent with the results of Sewell and Miller (1965), who reported that the apparent digestibility of the total lipid fraction of a diet containing corn oil was greater (P<.01) than diets containing either lard or tallow. According to their research, although there were no significant differences in gain due to fat source, pigs fed the corn oil supplemented diet tended to gain more rapidly. In general, the type of fat incorporated into the diet appeared to influence fat utilization by the pig. The researches theorized that this could be attributed to the fatty acid composition of the fats.

The Effect of Fatty Acid Composition on Fat Utilization

Individual fatty acids appear to be utilized to a different extent by the young pig. Differences in absorption and oxidation among fatty acids may be the major factor causing these differences in utilization. Lloyd and Crampton (1957) studied the effect of fatty acid chain length, measured by mean molecular weight, on apparent digestibility of fats or oils by young pigs. Using chromic oxide to estimate fat digestibility, twenty different fats were added individually to a low-fat basal ration at the level of 20 percent. A highly inverse relationship was found to exist between the mean molecular weight (chain length) of the fatty acids of various fats and oils and their apparent digestibility. Approximately 30% of the total variation in apparent digestibility was attributable to fatty acid chain length. Degree of saturation was found to exert minor influences on apparent fat digestibility.

The absorbability of individual fatty acids by early weaned pigs estimated from fecal samples was studied by Sewell and Miller (1965) utilizing corn oil, lard, and beef-tallow substituted for an equal quantity of corn starch and glucose in the basal diet. Oleic (18:1) and linoleic acid (18:2) were well absorbed (98%) from each of these diets, regardless of the amount or type of other fatty acids present in the diets. Furthermore, there were no significant differences in the absorbability of palmitate (16:0), oleic (18:1) or linoleic (18:2), although the absorbability of palmitate was slightly less in each instance. There was a decrease ($P<.01$) in the absorbability of stearic acid (18:0) as compared to the other three fatty acids. A lower absorbability of the 18:0 fatty acid was found in the diet containing corn oil as compared to the diets containing either tallow or lard. Absorbabilities were 28.5%, 81.4%, and 78.4% with corn oil-, tallow-, and lard- based diets, respectively. Apparently, the absorbability of the 18:0 fatty acid was depressed when fed in combination with high amounts of unsaturated fatty acids. These results are consistent with the results of Hamilton and McDonald (1969) who reported the apparent digestibility of palmitic and stearic acids as being lower than those of unsaturated or medium-chain saturated fatty acids.

The amounts of fatty acids in the digestive tract of pigs from 13 to 23 days of age was studied by Carlson and Bayley (1972) using a fat-soluble indicator of absorption, tridodecyl glyceryl ether (DGE). The authors postulated that the studies of fat digestion based upon dietary intakes and fecal outputs confound at least three processes: emulsification and absorption of fatty acids in the small intestine, additions of endogenous fat to digesta, and modifications of unabsorbed fat residues in the large intestine. Ten percent beef tallow replaced ten percent glucose in the experimental diets. One diet was fed with DGE and chromic oxide and one with chromic oxide only. Additionally, a third group was fed the control diet plus chromic oxide. DGE did not influence digestibility; therefore, it was accepted as an adequate marker. The calculations based upon the ratio of total fatty acid to chromic oxide suggested that there was a net secretion of fatty acids into the stomach. However, earlier observations suggested that this was due to separation of chromic oxide from the fatty acids in the stomach, with chromic oxide moving into the small intestine ahead of the fatty acids. Thus, meaningful absorbabilities of the fatty acids from the regions of the digestive tract distal to the stomach could not be calculated with chromic oxide as an indicator. In contrast, the calculations based upon the use of DGE show no change in the amount of fatty acid equivalent to a 1-kg diet as the digesta passed through the stomach, but showed a progressive net removal of fatty acids from the digesta for samples taken from successively lower regions of the small intestine.

The proportions of the saturated acids, palmitic and stearic, were greater in the digesta taken from successively lower regions of the digestive tract; stearic acid increased from 22% of the total fatty acids present in the beef tallow diet to 51% of the total in the colon contents derived from this diet. The composition of the fatty acids in the feces were similar to those in the contents of the colon.

The modifications of the fatty acids in the lower digestive tract, which occurred after the digesta had passed beyond the region where fatty-acid absorption is believed to be complete, cast doubt on the validity of using the digestibility of individual fatty acids from fecal samples as measures of the extent to which they can be absorbed from different fats by the animal.

The ileal absorbabilities of the fatty acids from beef tallow determined by comparative slaughter of piglets at 23 days of age were much greater for the total and for the saturated fatty acids than the digestibilities determined conventionally by collecting feces between the 13th and 23rd day of age. Changes in the fatty acid composition of fat in the large intestine could be a result of the addition of endogenous saturated fatty acids in the lower region of the digestive tract or of hydrogenation of unsaturated fatty acids by microflora of the large intestine. Likewise, Carlson and Bayley (1968) in a study using a conventional and a germ free pig reported that the low digestibility of steric acid and the high digestibility of oleic and linoleic acids appeared to be a result of microfloral activity rather than a direct result of the pig's ability to absorb these fatty acids. Freeman et al. (1968) produced direct evidence of biohydrogenation of oleic acid in the digestive tract of the piglet using ^{14}C-labelled oleic acid; these authors also showed that the extent of hydrogenation was dependent upon the type of fat in the diet. Therefore, the determination of either "apparent" or "corrected" digestibilities of the individual fatty acids in foods must be considered to be of limited usefulness in critical experiments designed to study the factors limiting fatty acid utilization by comparing feed intake and fecal output.

Although availability estimates obtained with ileal samples may not have the limitations observed with fecal samples, there is very limited information concerning fatty acid availability using illeally cannulated pigs. Only one study by Ozimek et al. (1984) has been reported in this area. They used 43-kg pigs fitted with a T-cannula 5 cm from the ileocecal junction to determine the ileal and fecal digestibility of fatty acids from two sources of fat markedly differing in fatty acid composition. Beef tallow (BT) and rapeseed oil (RO) were included at the level of 10% in cornstarch-based soybean meal diets. There were no differences (P>.05) between the ileal digestibility of fat in BT (84.6%) and RO (85.1%) and between the fecal digestibility of fat in BT (80.9%) and RO (81.8%). However, there were differences (P<.05) among the individual fatty acids. The ileal digestibility of the major fatty acids ranged from 60.4% (C18:0) to 94.1% (C18:1) in BT and from 66.8% (C16:0) to 97.8% (C18.:3) in RO. The fecal digestibility ranged from 33.4% (C18:0) to 98.8% (C18:2) in BT and from 45.8% (C16:0) to 99.6% (C18:2) in RO. The net increase in the level of fat that takes place in the large intestine, the increase in the level of saturated fatty acids and decrease in unsaturated fatty acids resulting mainly from microbial modification, suggests that samples should be taken from ileal digesta in order to obtain a valid indication of the pig's ability to digest fat.

In addition to differences in digestion, it has been reported that differences in the rate of oxidation of individual fatty acids may influence fatty acid utilization in the young pig. Wolfe et al. (1978), in order to test the differential metabolism of fatty acids, studied the effect of age and dietary fat level on the rate of oxidation of fatty acids in the neonatal pig. The rate of oxidation of ($U^{-14}C$) palmitate to CO_2 and acid soluble products was measured in homogenates of liver, kidney, heart, and leg muscle (biceps femotis) from pigs 0, 1, 7 and, 21 days of age. The relative rates of oxidation of ($U^{-14}C$) myristate, ($U^{-14}C$) palmitate, and ($U^{-14}C$) stearate were measured in homogenates of liver from 7 day old pigs. The rate of palmitate oxidation increased with age in liver, kidney, and leg muscle tissue and was maximum at 21 days in kidney, and leg muscle and at seven days in liver. The rate of palmitate oxidation in heart tended to decrease with animal age. In homogenates of liver from 7-day-old pigs, palmitate was oxidized at a faster rate than stearate or myristate.

Boyd et al. (1982) conducted an experiment to determine the rate of oxidation of palmitic (16:0), stearic (18:0), oleic (18:1) and linoleic acid (18:2) in fasting neonatal pigs. Oleic acid was oxidized at a more rapid rate (P<.05) than the other three fatty acids. Palmitic acid and linolenic were oxidized more rapidly than stearic acid, although the difference between 18:0 and 18:2 was not significant. Miller et al. (1971) studied the ability of the young pig to utilize individual fatty acids when differences due to digestion and absorption were eliminated by the intramuscular injection of labeled fatty acids. They reported that Lauric (12:0) was oxidized more rapidly than was palmitic acid (16:0) (P<.01), Oleic (18:1) and Linoleic (18:2) (P<.05). Oxidation rates between 18:1 and 18:2 were not significantly different although a trend toward faster oxidation of 18:1 was observed. No significant effects of age on fatty acid oxidation rates estimated by determation of cumulative $^{14}CO_2$ production were observed. However, there was a trend toward faster oxidation of these fatty acids in the older pigs. These results showed that medium-chain fatty acids are oxidized at a faster rate than long-chain fatty acids. A markedly greater oxidation rate of octanoate (8 carbons) relative to long-chain fatty acids was demonstrated in neonatal pigs by Duee et al. (1985) and Lepine (1987) using hepatocytes. These findings appear to coincide with the results of Frost and Wells (1981) who reported that medium-chain fatty acids are preferentially oxidized over long-chain fatty acid in the suckling rat. Thus, sources of fat abundant in medium-chain fatty acids should be evaluated as a dietary source of energy in early-weaned pigs.

Medium-Chain Triglycerides as a Dietary Source of Energy and Their Effect on Performance.

Medium-chain triglycerides are made up of a mixture of C6:0 (1 to 2%), C8:0 (65 to 75%), C10:0 (25 to 35%), and C12:0 (1 to 2%) medium-chain fatty acids obtained by the hydrolysis of coconut oil followed by the fractionation of the fatty acids. The medium-chain fatty acids are esterified with glycerol with or without a catalyst to form the triacylglycerols. The melting point of the medium-chain fatty acids is much lower (C8:0, 16.7°C; C10:0, 31.3°C).

Thus, medium-chain fatty acids and medium-chain triaciglycerols are liquid at room temperature. By virtue of their smaller molecular size, medium chain fatty acids are relatively soluble in water.

The molecular weight of MCFAs is smaller than the molecular size of long-chain triglycerides. Consequently, medium-chain tryglycerides are hydrolyzed both faster and more completely than long-chain triglycerides (Andre et al., 1982). Iber (1974) showed that the products of medium-chain triglyceride hydrolysis are absorbed faster than those of long-chain triglycerides, and as fast as glucose. Since the intraluminal hydrolysis of medium-chain triglycerides is rapid and relatively complete, the medium-chain triglycerides unlike long-chain triglycerides are absorbed mainly as free fatty acids, and only rarely as monodiacyglycerols. In cases where bile salts or pancreatic lipase deficiency or both occur, a large fraction of medium-chain triglycerides can be absorbed as triacylglycerols, whereas long chain triglycerides cannot be absorbed (Valdivieso, 1972).

In the mucosa, long-chain triglycerides are converted into ACYL-CoAs in the presence of an ACYL-CoA synthetase. The ACYL-CoAs are then incorporated into triacyglycerols, which are a major component of chylomicrons. Since this enzyme is specific for fatty acids with more than twelve carbon atoms, the MCFAs are not significantly incorporated into chylomicrons; therefore, MCFAs leave the intestine faster than the LCFAs (Andre et al., 1982).

Medium-chain fatty acids follow the portal venous system, whereas LCFAs follow the lymphatic system. The LCFAs are transported as chylomicrons, which are insoluble particles. The MCFAs, however, are transported in the soluble form of fatty acids bound to serum albumin. Because MCFAs leave the intestinal mucosa by the portal venous system, they reach the liver more directly and more rapidly than the longer molecules. Thus, MCFAs reach the liver in greater abundance than do exogenous LCFAS. Clark and Holt (1969) in a study with rats reported that when long-chain triglycerides and medium-chain triglycerides are ingested simultaneously, the latter partially inhibit the absorption of long-chain triglycerides. Nevertheless, the total number of calories absorbed in this situation was greater than the calories absorbed when either fat was ingested alone.

Mishkin et al. (1972) showed that in the endoplasmic reticulum of the hepatocyte, the LCFs are actively fixed on the fatty acid binding protein and activated into acyl-CoAs under the influence of a long-chain acyl-CoA synthestase. Because MCFAs do not bind easily to the fatty acid binding protein, MCFAs are almost never activated in the extramitochondrial space. MCFAs cross the double mitochondrial membrane very rapidly and, unlike the LCFAs, do not require the presence of carnitine. The medium-chain triglycerides are rapidly oxidized. Bach et al. (1976)

found that during the accelerated β-oxidation of MCFAs, many hydrogen atoms are released, and thus the cell medium is noticeably reduced. Scheig (1968) reported that the liver produces about ten times more CO_2 from C8:0 than from C16:0; but the capacity of the krebs cycle is limited. Because of the excess of acetyl-CoA produced from medium-chain triglycerides and the reduction in the cell medium, oxaloacetate will be in short supply. A large part of the acetyl-CoA is then redirected toward the synthesis of ketone bodies. A modest elevation in the concentration of ketone bodies in the blood is known not to be dangerous: all the extralypatic tissues can use the ketone bodies supplied by the blood. Furthemore, Robinson et al. (1980) reported that when the blood level of β-hydroxybutyrate and acetoacetate increases, the utilization of ketone bodies is enhanced.

Andre et al. (1982) cited some of the beneficial effects of the uses of medium-chain triglycerides: 1) medium chain triglycerides are digested, absorbed, and transported easily and rapidly; 2) medium-chain triglycerides are oxidized rapidly in the organism and they have a very low tendency to deposit as body fat; 3) medium-chain triglycerides are a source of abundant and rapidly available energy; 4) medium-chain triglycerides are ketogenic; and 5) medium-chain triglycerides are donors of hydrogen ions and precursors of acetyl-CoA.

Because of the benefits cited earlier, medium-chain triglycerides could offer some advantages in reducing the weaning stress problems associated with early weaning in pigs. However, very little research has been conducted in this area. Newport et al. (1979) using 2-day weaned pigs, studied the effect of medium chain triglycerides on live weight gain, feed:gain ratio, carcass composition, and blood lipids. The diets contained 730 g dried skim milk and 270 g fat/kg dry matter. Three diets were compared in which the fat was supplied as soybean oil (SO) (Diet A), equal amounts of SO and medium chain triglycerides (Diet H), or 246g medium chain triglycerides and 24 g SO (Diet I)/kg dry matter. In the later diet, soybean oil ensured that the diet had an adequate content of essential fatty acids. Growth rate (2-28 days of age) was reduced ($P<.05$) by a high medium-chain triglyceride diet (Diet I) when compared with the medium medium-chain triglyceride diet (Diet H), but in comparison with Diet A, the differences were not significant ($P>.05$). Overall, the proportion of fat in the carcass was reduced, particularly by Diet I ($P<.001$) and was inversely related to an increase mainly in the water content, and to a lesser extent, in the crude protein content of the carcass.

The relative effectiveness of medium-chain triglycerides (an alternative to sow colostrum) and colostrum in increasing plasma FFA, glucagon, and glucose concentrations was evaluated by Lepine et al. (1989) using neonatal pigs. They reported that medium chain triglyceride supplementation promotes improved glucose status of the fasting neonatal pig, however; a preliminary study conducted to determine whether the effect on glucose status was sufficient to enhance survival of the smaller, less competitive neonatal pigs indicated that plasma glucose concentration ($P<.10$) and the percentage survival at 30 hours ($P<.08$), 7-day ($P<.10$) and 21-day postpartum were lower for the medium-chain triglycerides dosed (25 ml of medium-chain triglycerides twice within the initial 24-hour postpartum) neonates compared with the saline dosed (25 ml) controls. The authors explain that this may have resulted from an excessive volume of medium chain triglycerides, which promoted a degree of satiety that interfered with the pattern of nursing and the quantity of nutrient consumed (glucose, triglyceride and fatty acids). Recipients of medium chain triglycerides in the nursing group appeared lethargic and less active. Cholecystokinin has been determined in many species, including swine, to produce satiety (Anika et al., 1980). Certain amino acids and fatty acids cause release of cholecystokinin from duodenal mucosa.

Odle et al. (1988) conducted an experiment to determine if piglets that were six hours, eighteen hours or fourty eight hours old responded differently to a 12 medium-chain triglyceride oral load of even chain medium chain triglyceride, odd chain- medium chain triglycerides or corn oil, a long-chain triglyceride. Pigs from each treatment were fasted one hour and then given orally 12 ml of either an even chain triglyceride (C-8, C-10), an odd chain triglyceride (C-9) or corn oil, a long chain triglyceride.

Whole blood samples were collected and prepared at 0, 1, 2, 4 and 8 hour after the triglycerides were fed. These samples were analyzed for B-hydroxy butyrate (BHBA, as an indicator of ketone bodies) and C-8, C-9 and C-10 fatty acids. ThIs data indicated that the major change in the metabolism of medium chain triglycerides occurs when the piglet is between six and eighteen hours old. There was a marked increase in the blood concentration of BHBA and C-8 in the eighteen hours versus the six hours old piglets suggesting a major change in the piglet's ability to absorb and/or utilize the C-8 fatty acid. The low concentration of BHBA when long chain triglycerides was used implies that the rate of absorption and/or metabolism of this fat is slow. This observation suggests that long chain triglycerides may not be the fuel of choice because it provides energy too slowly.

CHAPTER III

THE EFFECT OF FAT SOURCE AND MEDIUM-CHAIN TRIGLYCERIDE LEVEL ON PERFORMANCE OF THE EARLY-WEANED PIG

Summary

The effect of dietary fat source and medium chain triglyceride level was studied in two trials utilizing 71 early-weaned pigs (22 - 23 days). The five treatment groups were all fed diets containing 10% fat. Fat sources used were butterfat (T1), lard (T2), 8% lard:2% captex 300 medium-chain triglycerides (T3), 6% lard:4% captex 300 medium-chain triglycerides (T4) and 4% lard:6% captex 300 medium-chain triglycerides (T5). Pigs were housed in an environmentally controlled room in individually elevated pens with temperature maintained at 31°C and 29°C for weeks 1 and 2 respectively. Trial length was fourteen days with gain and efficiency of gain estimates obtained weekly. All pigs were fed a common 18% crude protein starter diet for an additional 3-week period to evaluate post-treatment effects on gain and efficiency of gain. There were no significant differences in average daily gain between pigs fed butterfat and lard, although pigs fed butterfat tended to grow faster. There was a linear increase (P<.01) in average daily gain

with increasing level of medium-chain triglycerides in the ration during week 1 and during the 2-week experimental period. Least square means for average daily gain for treatments 1 through 5 were 252.4, 213.2, 263.0, 277.2, and 316.8 during week 1 and 339.3, 325.4, 343.6, 360.3, and 381.5 g/day respectively, for the 2-week period. Gain-to-feed ratio during the first week and during the overall 14-day experimental period increased linearly ($P<.01$) as medium-chain triglycerides increased in the diet. No differences ($P>.76$) were observed among dietary treatments for average daily feed intake (ADFI), although pigs fed medium-chain triglyceride-supplemented diets had a greater actual intake than those fed the lard-supplemented diet (Treatment 2). Average daily gain, gain-to-feed ratio, and average feed intake during the subsequent 3-week period were not affected by treatment. Although the results of this study indicate that medium-chain triglyceride additions to the starter diet may improve performance during the first week postweaning relative to lard-and butterfat-supplemented diets, more research is needed to determine if adding higher levels of medium-chain triglycerides will continue to increase performance.

Introduction

Several studies have indicated that source of fat influences fat utilization by the young pig and that this differential in utilization may be partially due to fatty acid composition of the fat (Brawde and Newport, 1973; Cera et al., 1988; Lawrence and Maxwell, 1983; Lloyd and Crampton, 1957; Sewell and Miller, 1965). In addition, these studies indicated that sources of fat high in medium-chain or unsaturated fatty acids are preferentially utilized by the young pig. Research conducted by Wolfe et al. (1977) has suggested that the young pig is capable of efficiently utilizing a high fat diet when butterfat, which is an intermediate in both chain length and degree of saturation, is used as the fat source.

Recently, medium-chain triglycerides, which are made up primarily of a mixture of C8:0 (65 to 75%) and C10:0 (25 to 35%), have been manufactured and may offer an alternative fat source for the early-weaned pig. This study was conducted to compare lard with butterfat as a fat source and to determine the effect of replacing a portion of lard with medium-chain triglycerides (Captex 300 medium-chain triglycerides) on the performance of early-weaned pigs. All pigs were fed a common starter diet after the trial for a 3-week period to determine the effect of the 2 week trial period diet on subsequent performance.

Materials and Methods

Seventy-one Yorkshire pigs were used to compare lard with butterfat as a fat source and to determine the effect of different levels of medium-chain triglycerides on performance of early-weaned pigs. Thirty-six pigs in experiment one and thirty-five pigs in experiment two were allotted by sex, litter, and weight to one of five dietary treatments after being weaned at approximately 22-23 days of age, providing a total of 15 pigs in treatment one and 14 pigs in each of the other four treatments. During the first fourteen days (Period 1), treatment groups were fed diets containing 10% fat. Fat sources used were butterfat (T1), lard (T2), 8% lard:2% captex 300 medium-chain triglycerides (Capital City Products, Columbus, OH) (T3), 6% lard:4% captex 300 medium-chain triglycerides (T4), and 4% lard: 6% captex 300 medium-chain triglycerides (T5) (Table 3.1). Pigs had ad libitum access to feed and water. All diets were formulated to contain 1.40% Lysine, 0.90% Ca and 0.70% P (Table 3.2). Sources of fat were selected to vary in fatty acid composition (Table 3.3).

Pigs were individually housed in metabolism crates measuring 0.47 by 0.76 m in an environmentally controlled room. The temperature was maintained at 31 ^{o}C during the first week and was decreased $2^{o}C$ per week for the remainder of the experiment.

In the subsequent 21-day period (Period 2), all pigs were fed a common 18% crude protein diet (Table 3.4) to test for any carry-over effects from Period 1.

During the 5 week trial, individual pig weight was recorded, feed intake was measured, and feed efficiency (G:F) was calculated weekly. Waste feed was collected in pans directly under individual feeders and then dried in order to more accurately estimate feed intake. Protein, moisture, and ether extract of feed were determined by the official method of AOAC (1970). Methyl esters of the fatty acids of the dietary fats were prepared by adding 4.0 ml sodium-dried benzene, 0.4 ml DMP2, 2 - Dimethoxypropane, and 0.5 ml MeOH-HCl methonolic HCl to the fat sample. This was dried under nitrogen conditions and then diluted with sodium-dried benzene (Lawrence and Maxwell, 1983). Methyl esters were separated on a crosslinked 50% phenylmethyl silicone 25 m x 0.2 mm x 0.17 mm film thickness column in a gas-liquid chromatographic column instrument with a flame ionization detector operated at 190^{o}C. Temperature program was 125^{o}C - 225^{o}C at 10^{o}/min.

One pig from Experiment 1 and 4 pigs from Experiment 2 were eliminated from the analysis due to prolonged feed refusal associated with the inability of these pigs to adjust to the nipple waterers. It should be noted that these pigs were removed from different treatments, and the four of this group were from the same litter.

Data were analyzed using least-squares analysis of variance. The standard error reported for each period is the pooled mean of the standard errors of all treatments. The model for average daily gain, feed efficiency, and average daily feed intake (ADFI) included the main effects of experiment, treatment, sex, and litter within experiment and the appropriate interactions with initial weight on test as a covariate. The difference between means was determined by a t-test. Orthogonal polynomials were used to test for linear, quadratic, and cubic effects for the different levels of medium-chain triglyceride. Week and the appropiate interactions were added to the model for analysis of pig weight.

Results and Discussions

The effect of dietary fat source and medium-chain triglyceride level on average daily gain is shown in Table 3.5. During the first week, pigs fed diet 1 (10% butterfat) grew 18% faster than those fed diet 2 (10% lard) although differences between the means were not significant.

Average daily gain during the first week increased with increasing level of medium-chain triglycerides in the diet (diet 2 to diet 5, linear effect, $P<.01$). These results indicate that the level of medium-chain triglycerides improved gain and had the greatest effect on gain when added at the highest level (6 %) in the diet. Pigs fed diet 5, which contains 6% medium chain triglycerides and 4% lard, outperformed those fed diet 2 (10% lard), and diet 3 (8% lard:2% MCT) by 49 and 20%, respectively. In addition, pigs fed diet 4 (6% lard:4% MCT) grew 30% faster than those fed diet 2. Average daily gain over the entire 14-day experimental period continue to be greater for pigs fed diet 1 than for those fed diet 2; however this difference was lower than that observed during the first week. As was observed in week 1, average daily gain increased linearly

(P<.01) with increasing level of medium-chain triglyceride in the diet during the entire 14-day experimental period. Pigs fed diet 5 grew 17% faster than those fed diet 2 and 11% faster than those fed diet 3. Least square means for average daily gain for treatment 1 to 5 were 339.3, 325.4, 343.6, 360.3, and 381.5 g/day respectively. Average daily gain was similar among all treatments during the subsequent 3 weeks (day 14 to 35), although pigs fed diet 2 continued to show reduced gains when compared to pigs fed the others diets.

Initial pig weights averaged 6.37, 6.87, 6.54, 6.54, and 6.77 kg for Treatments 1 through 5, respectively (Table 3.6). After week 1, pigs fed diet 1 showed greater weight than those fed diet 2. Pig weight increased linearly with increasing level of medium-chain triglycerides in the diet during the first two weeks on trial (P<.01, Table 3.6). Differences in pig weight continued throughout the third week carryover period when pigs were fed a common diet. A linear increase in pigs weight at the end of week 3 (P<.01), week 4, and week 5 (P<.05) was observed with increasing the amount of medium-chain triglyceride in the diet. Pigs fed diet 2 weighed less at the completion of the trial when compared to the other dietary treatments; however, differences were not significant. No significant treatment by week interaction (P>.94) was observed and differences in weight during the final three weeks were primarily the results of differences observed in weight gain during the initial 2 week experimental period.

Feed required per unit of gain followed a pattern similar to that observed for gain (Table 3.7). Pigs fed diet 1 gained 15% more per gram of feed during the first week on trial than those fed diet 2, although this difference was not significant. Gain-to-feed ratio increased linearly as medium-chain triglycerides increased in the diet ($P<.01$). Pigs fed diet 5 had a 33% and 16% higher gain-to-feed ratio (G:F) than those fed diet 2 and 3, respectively. Also pigs fed diet 4 had a 22.5% higher gain-to-feed-ratio than those fed diet 2 . Least square means were 0.92, 0.80, 0.92, 0.98, and 1.07 g gain/g feed for treatments 1 through 5, respectively. Over the entire 14-day experimental period, efficiency of feed utilization increased linearly ($P<.01$), along with increasing medium-chain triglyceride levels in the diet. Least squares means for treatments 1 to 5 were 0.89, 0.84, 0.89, 0.91 and 0.96 g gain/g feed, respectively. Gain-to-feed ratio was similar among all treatments during the subsequent 3-week period .

The effect of the dietary fat source and the medium-chain triglyceride level on average daily feed intake (ADFI) is presented in Table 3.8. Average daily feed intake during the first week was similar among all treatments, although pigs fed the diet supplemented with butterfat consumed 6% more feed per day than those fed lard. Pig fed the medium-chain triglyceride-supplemented diet at the level of 6%

(treatment 5) had 14% greater intake when compared to pigs fed the lard-supplemented diet (treatment 2). Least squares means were 271.9, 257.2, 281.5, 284.0, and 292.2 g/d for treatment 1 to 5, respectively. Average daily feed intake during the overall 14-day experimental period was similar among treatments, even though pigs fed medium-chain triglyceride supplemented diets had greater intakes when compared to pigs fed lard-supplemented diet. The effect of medium-chain triglyceride level on ADFI during the subsequent 21-day period was similar to that observed in period 1, with a trend toward increased feed intake in pigs fed the medium-chain triglycerides supplemented diets when compared to pigs fed the lard supplemented diet.

In general, diet supplementation with butterfat, which is an intermediate in both chain length and degree of saturation, did not significantly affect average daily gain and gain-to-feed ratio relative to the lard supplement diet; however, pigs fed butterfat show greater average daily gain and G:F than pigs fed lard. Lawrence and Maxwell (1983) and Frobish et al. (1970) also reported that pigs fed butterfat had better performance than those fed lard, but these differences were not significant.

Diet supplementation of early-weaned pigs with 6% medium-chain triglycerides significantly increased average daily gain and feed efficiency (G:F) during the first week postweaning relative to diets supplemented with 10% lard or butterfat. Also, there was a linear response in average daily gain and G:F, with increasing levels of medium-chain triglycerides during the overall 14-day experimental period. Although the mechanism by which medium-chain triglycerides improved the average daily gain and the gain-to-feed ratio cannot be determined from the present study, a number of possibilities exist. Fatty acids of medium-chain triglycerides are readily hydrolyzed and absorbed from the digestive tract and transported to the liver via the portal vein, thereby enhancing the opportunity for hepatic uptate. In addition, medium-chain fatty acids do not require the carnitine acylthransferase system for transport into the mitochondria for oxidation (Breemer, 1983). As such, medium chain fatty acids could result in greater potential for hepatic uptake and oxidation of medium-chain fatty acid compared with the long-chain fatty acids (Frost and Wells, 1981).

Lloyd and Crampton (1957), reported a highly inverse relationship between mean molecular weight (chain length) and apparent digestibility, with short-chain fatty acids being more efficiently utilized than long-chain fatty acids. Frobish et al. (1970) and Lawrence and Maxwell (1983), reported that young pigs showed greater and more efficient gains when fed lower molecular weight fat sources (butterfat and coconut oil) than those fed higher molecular weight fats (lard, corn oil, and soybean oil). The authors suggested that the differential performance of pigs may be partially due to the fatty acid composition of the fat. Contrary to these results, Allee et al. (1972), using five-week-old pigs reported, no differences in performance in pigs fed 10% corn oil, lard, coconut oil, medium-chain triglycerides, or the control diet (1% tallow). The discrepancy may be partially due to differences in the age of the pigs used. Results of a study conducted by Newport et al. (1979) using pigs weaned at two days indicated that medium-chain triglycerides had very little effect in improving gain and feed efficiency when the medium-chain triaglyceride replaced half of the soybean oil in a 27% fat liquid diet. When 90% of dietary lipid was supplied by medium-chain triglycerides, there was a significant reduction in growth rate as compared to a 13.5% medium-chain triglyceride diet, but there were no differences when compared to the 27% soybean oil diet.

Several studies indicated that short-chain fatty acids are oxidized more rapidly than long chain fatty acids. Duee et al. (1985) and Lepine et al. (1987) using hepatocytes of neonatal pigs reported a greater oxidation rate of octanoate (8 carbons) relative to long-chain fatty acids. Miller et al. (1971) reported that lauric acid was oxidized more rapidly than palmitic, oleic, and linoleic acid, suggesting that short chain fatty acids are oxidized more rapidly than long chain fatty acids, an observation which generally supports the finding of this study.

In general, the results of this study indicate that faster growth and a higher gain-to-feed ratio can be achieved during the first week postweaning when pigs weaned at 3 weeks of age are fed a diet supplemented with 6% medium-chain triglycerides and 4% lard in place of a diet supplemented with 10% lard or 10% butterfat. Similar gain and efficiency of gain can be achieved after the first week postweaning. Feeding butterfat to the young pig during the first week postweaning appears to provide some advantage over lard; however, differences were relatively small. Further studies are necessary to evaluate the effect of higher levels of medium-chain triglycerides on the growth and performance of young pigs. In addition, more research should be conducted to compare medium-chain triglycerides with other sources of fats. Finally, studies in fatty acid availability using illeal cannulation in the early-weaned pig are necessary before the utilization of dietary fat may be predicted from its fatty acid composition.

TABLE 3.1

COMPOSITION OF DIETS FED DURING PERIOD 1 (2 WEEK)

Ingredient	Diets[a]				
	1	2	3	4	5
Soybean meal, 50%	14.00	14.00	14.00	14.00	14.00
Whey, dried whole	20.00	20.00	20.00	20.00	20.00
Dried skim milk	10.00	10.00	10.00	10.00	10.00
Corn, ground	37.73	37.73	37.73	37.73	37.73
Butterfat[b]	10.00	00.00	00.00	00.00	00.00
Lard[b]	00.00	10.00	8.00	6.00	4.00
Captex 300 MCT[bc]	00.00	00.00	2.00	4.00	6.00
Fish meal	6.00	6.00	6.00	6.00	6.00
Lysine, HCl	0.18	0.18	0.18	0.18	0.18
Calcium carbonate	0.33	0.33	0.33	0.33	0.33
Dicalcium phosphate	0.42	0.42	0.42	0.42	0.42
Apralan	0.10	0.10	0.10	0.10	0.10
Vit.TM premix[d]	0.94	0.94	0.94	0.94	0.94
Salt	0.30	0.30	0.30	0.30	0.30
	100.00	100.00	100.00	100.00	100.00

[a]As fed basis.
[b]Each was stabilized with ethoxyquin (624 ppm).
[c]From Capital City Products Company, Columbus, Ohio.
[d]Supplies 8,800 IU Vitamin A, 880 IU Vitamin D, 37 IU Vitamin E, 44 mg Panothenic acid, 59 mg Niacin, 8.8 mg Riboflavin, 7.3 mg menadione, .04 mg Vitamin B_{12}, 880 mg choline chloride, .2 mg selenium, .06 g manganese, .2 g zinc, .2 g iron, .2 g copper, .4 mg iodine, 3 mg biotin, 8.7 mg pyridoxine, 2 mg folic acid, 10 mg thiamine, per kg of feed, .02% Magnesium and .10% potassium.

TABLE 3.2

CALCULATED AND ACTUAL ANALYSIS OF DIETS FED DURING PERIOD 1 (2 WEEK)

	Diets[a]				
	1	2	3	4	5
Calculated analysis					
Crude protein	19.67	19.67	19.67	19.67	19.67
Calcium	.90	.90	.90	.90	.90
Phosphorus	.70	.70	.70	.70	.70
Lysine	1.40	1.40	1.40	1.40	1.40
Tryptophan	.25	.25	.25	.25	.25
Threonine	.89	.89	.89	.89	.89
Met + cys	.72	.72	.72	.72	.72
M.E.(kcal/kg)	3681.70	3681.70	3681.70	3681.70	3681.70
Actual analysis					
Crude protein (N X 6.25)	19.75	19.48	19.90	20.00	20.00
Ether extract	14.49	14.56	14.71	14.60	14.63

[a]As fed basis.

TABLE 3.3

FATTY ACID COMPOSITION OF FATS

Fatty acid, %	Fat		
	Butterfat[a]	Captex 300[b]	Lard[a]
C 6[c]:0[d]		1.7	
C 8:0	1.4	68.6	
C 10:0	4.1	29.1	
C 12:0	4.7	0.6	
C 14:0	14.2		2.3
C 16:0	32.4		28.6
C 16:1	3.2		2.8
C 18:0	10.6		14.0
C 18:1	24.8		43.8
C 18:2	2.2		8.5
C 18.3	0.5		
	1.9		

[a]Fatty acid mehyl esters were separated on a crosslinked 50% phenylmethyl silicone 25m x 0.2mm x 0.17mm film thickness column in a perkin-elmer 5890 gas-liquid chromatographic equipped with a flame ionization detector operated at 285°C. Temperature program 125 - 225°C at 10.0°C/min.
[b]Analysis from Capital City Products Company, Columbus, OH.
[c]Number of carbon atoms in fatty acid.
[d]Number of double bonds in fatty acid.

TABLE 3.4

COMPOSITION OF DIET FED DURING PERIOD 2 (3 week)

Ingredient	% of diet[a]
Yellow corn	67.30
Soybean meal (44%)	28.50
Dicalcium phosphate	1.95
Calcium carbonate	.90
Vitamin TM premix[b]	.375
Lysine - HCl	.15
Salt	.40
Copper sulfate	.075
Banmith (pyrantel tartrate - 48g/lb)	.1
Mecadox - 10 (carbadox - 10g/lb)	.25
	100.00
Calculated composition of diet:	
ME, kcal/kg	3150.62
Lysine,%	1.10
Crude protein,%	18.48
Threonine, %	.75
Tryptophan, %	.22
Met + Cys,%	.61
Calcium,%	.85
Phosphorus,%	.70
Actual analysis:	
Crude protein (N x 6.25)	20.60

[a]As fed basis.
[b]Supplies 8,800 IU Vitamin A, 880 IU Vitamin D, 37 IU Vitamin, 44 mg panothenic acid, 50 mg niacin, 8.8 mg riboflavin, 7.3 mg menadione, .04 mg Vitamin B_{12}, 880 mg choline chloride, .2 mg selenium, .06 g manganese, .2 g zinc, .2 g iron, .2 g copper, .4 mg iodine.

TABLE 3.5

THE EFFECT OF FAT SOURCE AND MEDIUM-CHAIN TRIGLYCERIDE LEVEL ON AVERAGE DAILY GAIN (g/d)[a]

	Diet					
Item	1	2	3	4	5	SEM
No. of pigs	14	12	14	13	13	
d0-7[b]	252.4	213.2	263.0	277.2	316.8	19.5
d0-14[b]	339.3	325.4	343.6	360.3	381.5	13.0
d14-35	520.1	516.6	530.6	533.6	534.9	17.9

[a]LS means
[b]Linear response ($P<.01$) to increasing level of medium-chain triglyceride (treatment 2 to treatment 5).

TABLE 3.6

THE EFFECT OF FAT SOURCE AND MEDIUM-CHAIN TRIGLYCERIDE LEVEL ON PIG WEIGHT (kg)[a]

Item	Diet 1	2	3	4	5	SEM
No. of pigs	14	12	14	13	13	
In wgt	6.37	6.87	6.54	6.54	6.77	
Week 1[b]	8.38	8.10	8.45	8.55	8.82	0.13
Week 2[b]	11.36	11.17	11.42	11.65	11.95	0.18
Week 3[b]	14.18	14.01	14.17	14.71	14.99	0.27
Week 4[c]	18.11	17.66	18.46	18.39	19.05	0.42
Week 5[c]	22.28	22.01	22.57	22.86	23.18	0.40

[a]LS means
[b]Linear response ($P<.01$) to increasing level of medium-chain triglyceride (treatment 2 to treatment 5).
[c]Linear response ($P<.05$) to increasing level of medium-chain triglyceride (treatment 2 to treatment 5).

TABLE 3.7

THE EFFECT OF FAT SOURCE AND MEDIUM-CHAIN TRIGLYCERIDE LEVEL ON FEED EFFICIENCY (G:F)[a]

	Diet					
Item	1	2	3	4	5	SEM
No. of pigs	14	12	14	13	13	
d0-7[b]	0.92	0.80	0.92	0.98	1.07	0.05
d0-14[b]	0.89	0.84	0.89	0.91	0.96	0.02
d14-35	0.70	0.69	0.68	0.67	0.69	0.01

[a]LS means g gain/ g feed
[b]Linear response (P<.01) to increasing level of medium-chain triglyceride (treatment 2 to treatment 5).

TABLE 3.8

THE EFFECT OF FAT SOURCE AND MEDIUM-CHAIN TRIGLYCERIDE LEVEL ON FEED INTAKE (g/d)[a]

	Diet					
Item	1	2	3	4	5	SEM
No. of pigs	14	12	14	13	13	
d0-7	271.9	257.2	281.5	284.0	292.2	17.36
d0-14	376.7	375.0	380.6	391.0	391.2	14.20
d14-35	740.3	746.4	782.5	797.7	770.9	24.20

[a]LS means

CHAPTER IV

PRELIMINARY STUDY TO DETERMINE THE EFFECT OF INCREASING TALLOW AT THE EXPENSE OF LARD ON PERFORMANCE OF EARLY WEANED PIG

Summary

The effect of increasing the level of tallow at the expense of lard on the performance of early-weaned pigs was studied utilizing 25 Yorkshire pigs. The five treatment groups included fortified corn-soybean meal-whey diets containing 10% lard (T1), 9% lard:1% tallow (T2), 8% lard: 2% tallow (T3), 7% lard:3% tallow (T4), and 6% Lard:4% Tallow (T5). Pigs were individually penned in an environmentally controlled room and feed and water were offered ad libitum. Trial length was fourteen days with gain and efficiency of gain estimates obtained weekly. All pigs were fed a common 18% crude protein starter diet for an additional 3-week period to evaluate post treatment effects on gain and efficiency of gain. No difference ($P>.32$) was observed among dietary treatment for average daily gain during week 1 and during the 2-week experimental period. However, there was a trend to increased average daily gain as the percentage of tallow increased in the diet during the first week on trial (Linear effect, $P<.08$). Least square

means for week 1 were 211.3, 243.1, 254.1, 292.6, and 333.6 for treatment 1 through 5, respectively. The effect of dietary fat source on the efficiency of feed utilization was similar to that observed for average daily gain. Pigs fed the highest level of tallow had the greatest gain to feed ratio (G:F) during the first week on trial; however, this difference was not significant. Least square means for average daily feed intake were 270.2, 270.4, 288.0, 322.7, and 326.6 for T1 to T5, respectively. Performance during the subsequent 3 week period was not affected by treatment. The results of this preliminary study indicate that the replacement of lard with tallow (up to 4%) in a 10% fat supplemented diet has no effect on performance.

Introduction

Many studies have been conducted to evaluate the addition of animal fat to the starter diet to reduce the weaning stress problems in young pigs. Aherne et al. (1982) reported that the addition of lard to an adjusted starter diet improved average daily gain and feed conversion efficiency (P<.05) as compared to a control diet with no added fat. Leibbrant et al. (1975) reported that feed efficiency was improved with lard. However, studies by Brawde and Newport (1973) indicated that tallow, which is very similar to lard in fatty acid composition with the exception that tallow has approximately 74% more steric acid content than lard, is very poorly utilized by the young pig.

Studies by Cera et al. (1988) and Sewell and Miller (1965) indicated that pigs fed a tallow-supplemented diet performed similarly to those fed a lard-supplemented diet. Whether animal fat should be added to the starter ration and to determine if the young pigs can utilize lard and tallow to the same extent needs further investigation. This study was conducted to obtain preliminary data on the effect of replacing a portion of lard with tallow on the performance of early-weaned pig.

Material and Methods

A feeding trial was conducted with a total of 25 early weaned pigs to determine the effect of partial replacement of lard with tallow on performance. Pigs were allotted by sex, litter, and weight to one of five dietary treatments after being weaned at approximately 21 to 22 days of age, providing 5 pigs per treatment. During the first 14 days (Period 1), the five treatments included a fortified corn-soybean meal-whey diet (Table 4.1) containing 10% lard (T1), 9% lard:1% tallow (T2), 8% lard:2% tallow (T3), 7% lard:3% tallow (T4) or 6% lard:4% tallow (T5). Pig diets were formulated to contain 1.40% lysine, 0.90% Ca, and 0.70% P (Table 4.2). Fatty acid composition of lard and tallow is shown in Table 4.3. These pigs were individually housed in metabolism crates measuring 0.61 by 1.10 meters in an environmentally controlled room. The temperature was maintained at 31^{o}C during the first week and was decreased

$2^{o}C$ per week for the remainder of the experiment. Feed and water were offered ad libitum.

In the subsequent 21-day period (Period 2), all pigs were fed a common 18% crude protein diet (Table 3.4) to test for any carryover effects from Period 1.

During the 5-week trial, individual pig weight was recorded and feed intake measured. Waste feed was collected in pans directly under individual feeders and then dried in order to more accurately estimate feed intake.

Statistical analysis was performed using least-square analysis of variance. The model for average daily gain, feed efficiency, average daily feed intake (ADFI), and weight included the main effects of treatment, sex, litter, and the appropriate interactions with initial weight on test as a covariate. The difference between means was determined by a t-test. Orthogonal polynomials were used to test for linear, quadratic, cubic and quartic effects for the diferent levels of tallow.

Results and Discussion

The effect of replacing lard with tallow on average daily gain is shown in Table 4.4. Average daily gain during the first week increased linearly ($P<.08$), with increasing tallow levels in the diet. However, differences among treatment means were not significant ($P>.4$). Pigs fed diet 5 grew 58%, 37%, 31%, and 13% faster than those fed diets 1, 2, 3, or 4, respectively. Least square means were 211.3, 243.1, 254.1, 292.6, and 333.6 g per day during week 1 and 300.4, 299.5, 315.0, 330.0, and 361.9 g per day for the 2-week experimental period for treatments 1 through 5, respectively.

Initial pig weights averaged 6.23, 6.23, 6.30, 6.21, and 6.28 kg for treatments 1 through 5, respectively, when placed on trial (Table 4.5). At the end of the second week, pigs fed diet 5 had an 8% higher weight than pigs fed the lower levels of tallow; however, this difference was not significant.

Feed required per unit of gain during the first week followed a pattern similar to that observed for gain (Table 4.6). There was a trend for a higher gain-to-feed ratio when the percentage of tallow increased in the diet. However, these differences were not significant. Similar efficiency of gain was achieved after the first week postweaning in all treatments. Least square means during the first week for treatments 1 to 5 were 0.80, 0.83, 0.88, 0.89, and 1.04 g gain/ g feed, respectively.

The effect of replacing lard with tallow on average daily feed intake (ADFI) is presented in Table 4.7. Average daily feed intake during the first week was similar among all treatments, although pigs fed the diet supplemented with the higher level of tallow consumed more feed than those fed the other diets. Least square means for ADFI were 270.2, 270.4, 288.0, 322.7, and 326.7 for treatments 1 through 5, respectively. Performance during the subsequent three week period was not affected by treatment.

Partial replacement of lard with tallow in the early-weaned pig diet did not significantly affect average daily gain and gain-to-feed ratio relative to the diet supplemented with 10% lard. However, contrary to the expected results, there was a linear increase in average daily gain with increasing level of tallow in the diet during the first week postweaning. Tallow has approximately 74% more stearic acid content than lard and stearic acid is considered to be very poorly hydrolyzed (Sewell and Miller, 1965; Carlson and Bayley, 1972; Hamilton and MacDonald, 1969) and oxidized (Wolfe et al., 1978; Boyd et al., 1982) by the young pig. In this study the higher stearic acid content of the tallow supplemented diet may not have affected performance, possibly because this difference was not large enough to produce an effect on growth rate and feed efficiency. Cera et al. (1988) and Sewell and Miller (1965) also found no difference in performance between pigs fed lard-or tallow-supplemented diets. More research should be conducted in order to determine if adding higher levels of tallow will affect performance in early-weaned pigs.

TABLE 4.1

COMPOSITION OF DIETS FED DURING PERIOD 1 (2 WEEK)

Ingredient	Diets[a] 1	2	3	4	5
Soybean meal, 50%	14.00	14.00	14.00	14.00	14.00
Whey, dried whole	20.00	20.00	20.00	20.00	20.00
Dried skim milk	10.00	10.00	10.00	10.00	10.00
Corn, ground	37.73	37.73	37.73	37.73	37.73
Lard[b]	10.00	9.00	8.00	7.00	6.00
Tallow[b]	00.00	1.00	2.00	3.00	4.00
Fish meal	6.00	6.00	6.00	6.00	6.00
Lysine, Hcl	0.18	0.18	0.18	0.18	0.18
Calcium carbonate	0.33	0.33	0.33	0.33	0.33
Dicalcium phosphate	0.42	0.42	0.42	0.42	0.42
Apralan	0.10	0.10	0.10	0.10	0.10
Vit. TM premix[c]	0.94	0.94	0.94	0.94	0.94
Salt	0.30	0.30	0.30	0.30	0.30
	100.00	100.00	100.00	100.00	100.00

[a]As fed basis

[b]Each was stabilized with ethoxyquin (624 ppm).

[c]Supplies 8,800 IU Vitamin A, 880 IU Vitamin D, 37 IU Vitamin E, 44 mg Panothenic acid, 59 mg niacin, 8.8 mg riboflain, 7.3 mg menadione, .04 mg Vitamin b_{12}, 880 mg choline chloride, .2 mg selenium, .06 g managnese, .2 g zinc, .2 g iron, .2 g copper, .4 mg iodine, 3 mg biotin, 8.7 mg pyridoxine, 2 mg folic acid, 10 mg thiamine, per kg of feed, .02% Magnesium and .10% potassium.

TABLE 4.2

CALCULATED AND ACTUAL ANALYSIS OF DIETS FED DURING PERIOD 1 (2 WEEK)

Ingredient	Diets[a]				
	1	2	3	4	5
Calculated analysis					
Crude protein	19.67	19.67	19.67	19.67	19.67
Calcium	.90	.90	.90	.90	.90
Phosphorus	.70	.70	.70	.70	.70
Lysine	1.40	1.40	1.40	1.40	1.40
Tryptophan	.25	.25	.25	.25	.25
Threonine	.89	.89	.89	.89	.89
Met + cyc	.72	.72	.72	.72	.72
M.E. (kcal/kg)	3681.70	3681.70	3681.70	3681.70	3681.70
Actual analysis					
Crude protein (N x 6.25)	19.95	19.91	20.47	20.45	20.21
Ether extract	13.32	13.30	13.70	14.09	14.02

[a]As fed basis

TABLE 4.3

FATTY ACID COMPOSITION OF LARD AND TALLOW

Fatty Acid %[a]	Lard	Tallow
C12[b]:0[c]		0.3
C 14:0	2.3	3.8
C 16:0	28.6	24.0
C 16:1	2.8	1.7
C 18:0	14.0	24.4
C 18:1	43.8	39.1
C 18:2	8.5	6.7

[a]Fatty acid mehyl esters were separated on a crosslinked 50% phenylmethyl silicone 25m x 0.2mm x 0.17mm film thickness column in a perkin-elmer 5890 gas-liquid chromatographic equipped with a flame ionization detector operated at 285°C. Temperature program 125 - 225°C at 10.0°C/min.
[b]Number of carbon atoms in fatty acid.
[c]Number of doble bonds in fatty acid.

TABLE 4.4

THE EFFECT OF REPLACING LARD WITH TALLOW ON AVERAGE DAILY GAIN (g/d)[a]

Item	Diet 1	2	3	4	5	SEM
No. of pigs	5	5	5	5	5	
d 0-7[b]	211.3	243.1	254.1	292.6	333.6	52.4
d 0-14	300.4	299.5	315.0	330.0	361.9	46.4
d 14-35	575.2	602.5	575.7	602.5	614.6	26.3

[a]LS means
[b]Linear response ($P<.08$)

TABLE 4.5

THE EFFECT OF REPLACING LARD WITH TALLOW ON PIG WEIGHT (kg)[a]

Item	Diet 1	2	3	4	5	SEM
No. of pigs	5	5	5	5	5	
In wgt.	6.24	6.24	6.30	6.21	6.28	
Week 1	7.73	7.95	8.03	8.30	8.59	0.36
Week 2	10.46	10.44	10.66	10.87	11.32	0.64
Week 3	14.29	14.54	14.67	14.69	15.52	0.58
Week 4	18.68	18.90	18.81	19.17	20.23	0.77
Week 5	22.54	23.09	22.75	23.54	24.23	0.82

[a]LS means

TABLE 4.6

THE EFFECT OF REPLACING LARD WITH TALLOW ON FEED EFFICIENCY (G:F)[a]

Item	Diet 1	2	3	4	5	SEM
No. of pigs	5	5	5	5	5	
d 0-7	0.80	0.83	0.88	0.89	1.04	0.14
d 0-14	0.86	0.89	0.85	0.86	0.91	0.07
d 14-35	0.69	0.71	0.70	0.69	0.70	0.02

[a]LS means g gain/g feed

TABLE 4.7

THE EFFECT OF REPLACING LARD WITH TALLOW ON FEED INTAKE (g/d)[a]

	Diet					
Item	1	2	3	4	5	SEM
d 0-7	270.2	270.4	288.0	322.7	326.6	46.56
d 0-14	349.0	332.9	365.0	378.8	398.2	43.87
d 14-35	826.6	851.5	818.4	868.3	870.20	37.21

[a]LS means

LITERATURE CITED

Adams, K.L. and A.H. Jensen. 1985. Effect of dietary protein and fat levels on the utilization of the fat in sunflower seed by the young pig. Anim. Feed Sci. Techno. 13:159.

Aherne F.X., V. Danielsen and H.E. Nielsen. 1982. Fat utilization by three-week weaned pigs. Acta Agriculture Scandinavica. 32:151.

Allee, G.L., D.H. Balker and G.A. Leveille. 1971. Fat utilization and lipogenesis in the young pig. J. Nutr. 101:1415.

Allee, G.L. and R.H. Hines. 1972. Influence of fat level and calorie: protein ratio on performance young pigs. J. Anim. Sci. 35:210.

Andre, C.B. and V.K. Babayan. 1982. Medium-chain triglycerides:an update. Am. J. Clin. Nutr. 36:950.

AOAC. 1970. Official methods of analysis. Association of Official Agricultural Chemists. Washington, D.C.

Anika, S.M., T.R. Houpt and K.A. Houpt. 1980. Insulin as a satiety hormone. Physiol. S. Behav. 25:21.

Bach, A., T. Phan and P. Metais. 1976. Effect of the fatty acid composition of ingested fats on rat liver intermediary metabolism. Horm. Metab. Res. 8:375.

Balogun, O.O. and B.L. Fetuga. 1984. Influence of methionine and palm oil supplementation of cassava flour - soybean diets on performance, nitrogen and rate of tissue deposition in weaning pigs. Livest. Prod. Sci. 11:315.

Berschauer, F. 1986. Fats in diets for growing pigs. Pig News and Information. 7:153.

Boyd, R.D., D.M. Whitehead and W.R. Butler. 1985. Effect of exogenous glucagon and free fatty acids on gluconeogenesis in fasting neonatal pigs. J. Anim. Sci. 60:659.

Braude, R. and M.J. Newport. 1972. Artificial rearing of pigs. Br. J. Nutrition, 29:447.

Breemer, J. 1983. Carnitine-metabolism and functions. Physiol. Rev. 63:1420.

Carlson, W.E. and H.S. Bayley. 1972. Digestion of fat by young pigs: a study of the amounts of fatty acid in the digestive tract using a fat-soluble indicator of absorption. Br. J. Nutr. 28:339.

Carlson, W.E. and H.S. Bayley. 1968. Utilization of fat by young pigs: Fatty acid composition of ingesta in different regions of the digestive tract and apparent and corrected digestibilities of corn oil, lard and tallow. Can. J. Animal Sci. 48:315.

Cera, K.R., D.C. Mahan and G.A. Reinhart. 1988. Weekly digestibility of diets supplemented with corn oil, lard, or tallow by weaning swine. J. Anim. Sci. 66:1430.

Cera, K.R., D.C. Mahon and G.A. Reinhart. 1988. Effects of dietary dried whey and corn oil on weaning performance fat digestibility and nitrogen utilization. J. Anim. Sci. 66:1438.

Clark, S.B. and P. Holt. 1969. Inhibition of steady-state intestinal absorption of long-chain triglyceride by medium-chain triglyceride in unanesthetized rat. J. Clin. Invest. 48:2235.

Cline, T.R., J.A. Coalson, J.G. Lecce and E.E. Jones. 1977. Utilization of fat by baby pigs. J. Anim. Sci. 44:72.

DeMan, J.M. and J.P. Bowland. 1963. Fatty acid composition of sows' collostrum, milk and body fat as determined by gas-liquid chromatography. J. Dairy Res. 30:339.

Dieisen-Schade, D.A., M.J. Richard, D.C. Beitz and N.C. Jacobson. 1985. Effects of beef, soy and conventional diets on body composition and plasma, lipids of young pigs feed restricted or liberal amounts of diet. J. Nutr. 115:1016.

Duee, P.H., J.P. Pegorier, J. Peret and J. Girard. 1985. Separate effects of fatty acid oxidation and glucagon on gluconeogenesis in isolated hepatocytes from newborn pigs. Biol. Neoate. 47:77.

Edres, B., F.X. Aherne, L. Ozimek and H. Spicer. 1988. The effect of fat supplementation on ileal versus fecal fat digestibilities, performance and body composition of weaned pigs. Can. J. Anim. Sci. 68:225.

Eucebio, J.A., V.W. Hays, V.C. Speer and J.T. McAll. 1965. Utilization of fat by young pigs. J. Anim. Sci. 24:1001.

Fenton, J.P., K.L. Roehring, D.C. Mahan and J.R. Corley. 1985. Effect of swine weaning age on body fat and lipogenic activity in liver and adipose tissue. J. Anim. Sci. 60:190.

Freeman, C.P., D.W. Holme and D.W. Annison. 1968. The determination of the true digestibilities of interestierfied fats in young pigs. Br. J. Nutr. 22:651.

Freeman, C.P. 1969. Properties of fatty acids in dispersions of emulsified lipid and bile salt and the significance of these properties in fat absorption in the pigs and the sheep. Br. J. Nutr. 23:249.

Freeman, C.P. 1984. The digestion, absorption and transport of fat-non ruminant. In fats in animal nutrition. (Ad. J. Wiseman) pp. 105-122. Butterworths London.

Frobish, L.T., V.W. Hays, V.C. Speer and R.C. Ewan. 1969. Effect of diets form and emulsifying agents on fat utilization by young pigs. J. Anim. Sci. 29:320.

Frobish, L.T., V.W. Hays, V.C. Speer and R.C. Ewan. 1970. Effect of fat source end level on utilization by young pigs. J. Anim. Sci. 30:197.

Frobish, L.T., V.W. Hays, V.C. Speer and R.C. Ewan. 1971. Effect of fat source on pancreatic lipase activity and specificity and performance on baby pigs. J. Anim. Sci. 33:385.

Frost, S. and M.A. Wells. 1981. A comparison of the utilization of medium- and long-chain fatty acids for oxidation and ketogenesis in the suckling rat: in vivo and in vitro studies. Archives of Biochemistry and Biophysics. 211:537.

Hamilton, R.M.G. and B.E. McDonald. 1968. Effect of dietary fat source on the apparent digestibility of fat and the composition of fecal lipids of the young pigs. J. Nutr. 97:33.

Hanke, H.E., G. Castro and R.J. Deade. 1975. Influence of level of dietary protein and of supplemental tallow on rate of gain and feed/gain of pigs weaned at an early age. Minnesota Swine Research Reports. 24-29.

Iber, F. 1974. Relative rates of metabolism MCT, LCT and ethanol in man. In: Kaunitz H, Lang K, FcklW, eds. Mittelkettige Triglyceride in der Diat. 2 Ernahrungswiss. 17 (Suppl): 9.

Lawrence, N.J. and C.V. Maxwell. 1983. Effect of dietary fat source and level on the performance of neonatal and early weaned pigs. J. Anim. Sci. 57:936.

Leibbrandt, V.D., V.W. Hays, R.E. Ewans and V.C. Speer. 1975. Effect of Fat on performance of baby and growing pigs. J. Anim. Sci. 40:1081.

Leibbrant, V.D., R.C. Ewans, V.C. Speer and D.R. Zimmerman. 1975. Effect of age and calorie: protein ratio on performance and body composition of baby pigs. J. Anim. Sci. 40:1070.

Lepine A.J., R.D. Boyd, J.A. Welch and K.R. Roneker. 1989. Effect of colostrum or medium-chain triglyceride supplementation on the pattern of plasma glucose, non-estirified fatty acids and survival of neonatal pigs. J. Anim. Sci. 67:983.

Lewis, J.A., E.R. Peo., Jr., B.D. Moser and T.P. Crenshaw. 1981. Lysine requirement of pigs weighing 5 to 15 kg fed practical diets with and without added fat. J. Anim. Sci. 51:361.

Lloyd, L.E. and E.W. Crompton. 1957. The relation between certain characteristics of fats and oils and their apparent digestibility by young pigs, young guinea pigs and pups. J. Anim. Sci. 16:377.

Mach, P. and J. Prince. 1968. Sources of energy in suckling piglets. Veterinary Research Institute, Brno-Medlanky.

Miller, G.M., J.H. Conrad, T.W. Keenan and W.R. Featherston. 1971. Fatty acid oxidation in young pigs. J. Nutr. 101:1343.

Mishkin S., L. Stain, Z. Gatmaitan and I.M. Arias. 1972. The binding of fatty acids to cytoplasmic proteins: binding to Z protein in liver and other tissues of the rat. Biochem. Biophy. Res. Commun. 47:997-1003.

National Research Council. 1988. Nutrient requirements of swine. Ninth revised ed. Washington, D.C. National Academy Press.

Newport M.J., J.E. Storry and B. Tuckley. 1979. Medium chain triglycerides as a dietary source of energy and their effect on live-weight gain, feed:gain ratio, carcass composition and blood lipids. Br. J. Nutr. 37:187.

Odle, J., N.J. Benevenga and T.D. Crenshaw. 1988. Development of fat and ketone metabolism in the newborn pig. University of Wisconsin-Madison 25.

Okai, P.B. and S.J. Vroom. 1979. The effects of oil palm slurry on the performance of starter pigs. J. Anim. Sci. 49 (Suppl. 1):248. Abstr. 263.

Ozimek, L., W.C. Sauer, W. Kozixowski and Jorgensen H. 1984. The ilecal and fecal digestibility of fat and fatty acid in pigs fed semi-purified diets containing beef tallow or rapeseed oil. Agric. Bulletin- Alberta University. 14.

Perrin, D.R. 1955. The chemical composition of the colostrum and milk of the sow. J. Dairy Res. 22:103.

Robinson A.M. and D.H. Williamson. 1980. Physiological roles of ketone bodies as substrates and signals in mammalian tissue. Physiol. Rev. 60:143:187.

Scheig R. 1968. Hepatic metabolism of medium-chain fatty acids. In:Senior JR, ed medium-chain triglycerides. Philadelphia, PA: University of Pennsylvania Press, 39-49.

Scherer, C.W., V.W. Hays, G.L. Cromwell and D.D. Kratzer. 1973. Effect of diet and age on pancreatic lipase activity and fat utilization in pigs. J. Anim. Sci. 37:290 (Abstr.).

Sewell, R.F. and I.L. Miller. 1965. Utilization of various dietary fats by baby pigs. J. Anim. Sci. 24:973.

Souci, S.E., W. Fachman and H. Kraut. Food composition and nutrition table 1986/1987. 3rd ed. Wissenchqflitche Verlagsgesellschaft mbH Stuttgart, German, 1986.

Statlly, T.S. 1984. Use of fat in diets for growing pigs in animal nutrition (ed. J. Wiseman) pp.373. Butterworths, London.

Swiss, L.D., F.D. Horney and H.S. Bayley. 1976a. The composition of lipids in intestinal digesta of young pigs receiving diets containing tallow and tallow fatty acids. Can. J. Physical. Pharmacol. 54:728.

Swiss, L.D., and H.S. Bayley. 1976b. Influence of the degree of hydrolysis of beef tallow on its absorption in the young pigs. Can. J. Physiol. Pharmacol. 54:717.

Thaler, R.C., J.L. Nelssen and G.L. Allee. 1988. Effect of fat source and fat combinations on starter pig performance. Kansas State University Swine Day. 38.

Valdicieso, V. 1972. Absorption of medium-chain triglycerides in animals with pancreatic atrophy. Dig. Dis. 17:129.

Van Warmer, D.M. and D.S. Pollman. 1985. Effect of lecithin addition to starter pig diets with and without added fat and dry whey. Nutrition Reports International 32:801.

Walker, W.R., G.L. Morgan and C.V. Maxwell. 1986. Ileal cannulation in baby pigs with a simple T-cannula. J. Anim. Sci. 62:407.

Wolfe, R.G., C.V. Maxwell, E.C. Nelson and R.R. Johnson. 1977. Effect of dietary fat level on growth and lipogenesis in the colostrum deprived neonatal pig. J. Nutr. 107. 2100.

Wolfe, R.G., C.V. Maxwell and W.C. Nelson. 1978. Effect of age and dietary fat level on fatty acid oxidation in the neonatal pig. J. Nutr. 108:1621.

2

VITA

Brenda De Rodas

Candidate for the Degree of

Master of Science

Thesis: FAT UTILIZATION BY THE EARLY WEANED PIG

Major field: Animal Science

Biographical:

Personal data: Born in San Ignacio F.M., Honduras C.A., November 27, 1959, the daughter of Jose and Marina Escober.

Education: Graduated from the "Vicente Caseres" institute, Tegucigalpa, Honduras, in November 1976; received Bachelor of Science Degree in Agronomous Engineering from The National University of Honduras in August, 1982; completed requirements for the Master of Science degree at Oklahoma State University, July, 1989.

Professional Experience: Coordinator of farmer cooperative unions as a representative of the Agriculture Department of Honduras, March, 1981 to May, 1984. Worked in The Extension Division of the Agriculture Department of Honduras June 1984, to August, 1986.