THE EFFECT OF REPLACING LARD WITH TALLOW ON PERFORMANCE AND FAT DIGESTIBILITY IN EARLY WEANED PIGS

By

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CHAPTER I

INTRODUCTION

Removal of the pig from the sow earlier than 4 to 5 weeks of age can be considered early weaning and can be economically advantageous to the swine producer. This practice will shorten the reproductive cycle of the sow herd and allow placement of females back into production sooner with the expectation of rearing more pigs per sow per year and thus maximizing profit. Subjecting a three week old pig to the distress of weaning results in a "postweaning lag syndrome" during a five to ten day period after weaning. This is characterized by decreased feed intake, reduced gain or weight loss, and diarrhea. It is also common to observe a higher incidence of mortality when compared to those weaned at an older age. Both the drastic change in the diet and the change in environment are stress factors contributing to the reduction in performance. Since sows' milk contains approximately 30 percent fat (DM basis), it has been suggested that feeding diets supplemented with a very high quality fat could reduce the "postweaning lag syndrome". However, the piglet has a limited ability to digest some types of fat. The fat digesting enzyme, lipase, can easily digest the small fat globules found in milk. The ability to digest other types of fat has been questioned and appears to increase with time.

It is of interest to the swine industry to ascertain if adding fat will reduce postweaning lag and result in faster growing, more efficient pigs.

A large number of studies have been conducted to evaluate the performance of early weaned pigs fed fat supplemented diets. The interpretation of these results has been complicated by inconsistent fat composition (due to fat sources) and different levels of lipid additions as well as differences in age and in the nutrient:energy ratio of the diet. Many researchers (Sewell and Miller, 1965; Hamilton and MacDonald, 1969; Lawrence and Maxwell, 1983; Thuher et al., 1988; DeRodas and Maxwell, 1989; Li et al., 1989ab) have observed considerable variation in the utilization of various types of dietary fat. Difference in fat composition appears to be one of the major sources of variability in performance response to added fat.

It is well documented that sources of fat high in short and medium-chain fatty acids are more effectively utilized by the young pig than those containing predominantly long-chain fatty acids (Cera et al., 1989c; DeRodas and Maxwell 1989). In addition, degree of saturation of fatty acid is important in determining the degree of fat digestibility of pigs (Li et al., 1989b). Lloyd et al. (1957) and Cera et al. (1988a) demonstrated differences in fat digestibility in pigs between 3 and 7 weeks of age, whereas Hamilton and

MacDonald (1969), Frobish et al, (1969,1970) and Braude and Newport (1973) reported that fat digestibility was unaffected by piglet age.

Some of the inconsistency in these studies may be related to the methodology used in lipid analysis (Lloyd and Cramptom, 1957; Hamilton and MacDonald 1969; Frobish et al.,1970) and methodology of estimating digestibility of fats used (Ozimek et al., 1983).

Several studies have been conducted to evaluate the performance of early weaned pigs fed animal fat supplemented diets (Eucebio et al.,1965; Frobish et al., 1970; Allee et al., 1971; Braude and Newport, 1973; Aherne et al., 1982; Lawrence and Maxwell, 1983; Cera et al., 1988; DeRodas and Maxwell, 1989;). Cera et al.(1988a, 1989c) observed a difference in apparent fat digestibility between long chain unsaturated (corn oil) and saturated (tallow, lard) triglyceride supplemented diets over a 4 week postweaning period. The apparent digestibility of fat within each weekly period was similar for the tallow and lard-supplemented diets. Tallow has approximately 74% more stearic acid content than lard and stearic acid is considered to be both poorly hydrolyzed (Sewell and Miller, 1965; Hamilton and MacDonald, 1969; Carlson and Bayley, 1972) and oxidized (Wolfe et al., 1978; Boyd et al., 1982; Pegorier et al., 1983) by the young pig. However, research has failed to document whether the young pig is capable of utilizing tallow as effectively as lard.

This study was conducted to determine the effect of two dietary fat sources on the performance of early weaned pigs. The specific objectives of this study were: 1) to compare the effect of diets containing ten percent lard with increasing levels of substitution of lard with tallow on gain and efficiency of gain in early weaned pigs and 2) to determine the effect of increasing replacement of lard with tallow on dry matter, fatty acid and total fat digestibility at days 7 and 14 after weaning.

CHAPTER II

LITERATURE REVIEW

Preweaned pigs have traditionally performed well from three to six weeks of age when allowed to continue nursing the sow and given access to a supplemental creep ration. However, when pigs are weaned at an early age and abruptly supplied a dry corn-soybean meal diet, a period of poor performance commonly referred to as the "Postweaning lag syndrome" occurs (Okai et al., 1976). Since sow's milk is efficiently utilized by the pig and contains 30 percent fat on a dry matter basis, it has been suggested that feeding diets supplemented with a very high quality fat in the early weaning diet may alleviate this lag syndrome (Perrin, 1955; DeMan and Bowland, 1963).

Several studies have been conducted to evaluate the effect of fat in the diet of early weaned pigs. The results of these studies often conflict, possibly due to several factors such as type and level of fat, differences in age of pigs, and differences in the nutrient to energy ratio used in the diet (Eucebio et al., 1965; Frobish et al., 1970 Allee and Hines, 1972; Braude and Newport, 1973; Aherne et al., 1982; Lawrence and Maxwell, 1983).

The type of fat incorporated in the diet appears to influence fat utilization by the pig. The variable effect of fat on performance could be attributed to fatty acid composition of the fat (Hamilton and MacDonald, 1969; Braude and Newport, 1973; Lawrence and Maxwell, 1983; Cera et al., 1988; Cera et al., 1988a,1989b; Li et al., 1989a).

In addition to differences in digestibility of fatty acids, Miller et al. (1971), Wolfe et al. (1978), and Boyd et al. (1982) reported differences in rate of oxidation of individual fatty acids by liver tissue and Pegorier et al. (1983) observed that the piglet has a limited capacity of oxidation of individual fatty acids.

The interpretation of results has been complicated by varying sources and levels of fat as well as differences in age of pigs. Much research has been conducted in this area to compare levels as well as source, however, data fail to document whether the young pig is capable of utilizing tallow as effectively as lard.

Effect of Dietary Fat Source on Performance in Early Weaning Pigs

Source of fat influences the ability of the young pig to utilize fat supplemented diets. Li et al. (1989a) studied the effect of fat addition on starter pig performance using soybean oil, coconut oil, 50% soybean oil;50% coconut oil, 75% soybean oil;25% coconut oil and 25% soybean oil;75% coconut oil. Diets were supplemented with 10% fat for the first two weeks of the study and 5% fat for the final 3 weeks. Pigs fed diets containing 50% soybean oil; 50% coconut oil improved in average daily gain (ADG) (P<.05) when compared to pigs fed either the control diet or the soybean oil supplemented diet. Aherne et al. (1982) reported that the addition of 10 percent lard to an adjusted (protein to energy ratio was held constant) starter diet improved average daily gain and feed efficiency. Likewise, Leibbrant et al. (1975) reported that feed efficiency was improved with the addition of lard to the early weaned pig diet. The utilization of various dietary fats by early-weaned pigs was studied by Lawrence and Maxwell (1983). These workers utilized pigs weaned at 0 days of age and fed a liquid semi-purified diet for 20 days to study the effect of four dietary fat sources on performance. The diets contained 32% butterfat, corn oil, coconut oil, or lard on dry matter basis.

Gain and efficiency of feed utilization were greater (P<.05) for the pigs fed coconut oil than for pigs fed corn oil or lard. Pigs fed the butterfat-supplemented diet performed better than pigs fed a lard and corn oil-supplemented diet, but the differences were not significant. Frobish et al. (1970) and DeRodas and Maxwell (1989) also demonstrated that pigs fed butterfat had better performance than those fed lard, but these differences were also not significant. Thaler et al. (1988) in two five-week trials utilized treatments consisting of a control with no added fat, and fat addition of either soybean oil (SOY), coconut oil (COCO), choice white grease (CWG), half SOY;half COCO (SOCO) or half CWG;half COCO (CWCO). Diets were supplemented with 10 percent fat for the first two weeks of the study and five percent 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 addition 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 ($P<.05$).

The utilization of various fats by early weaned pigs was studied by Sewell and Miller (1965) utilizing corn oil, lard and beef tallow substituted for equal quantities of corn starch and glucose in the basal diet. There were no significant differences in gain due to fat source. However, pigs fed corn oil tended to gain more rapidly than those fed other fat sources. Braude and Newport (1973) studied the effect 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 26 days. The performance of the pigs and the apparent digestibility of the dietary fat indicated that soybean oil was equal to butterfat. Butterfat was slightly superior to coconut oil and markedly superior to beef tallow. There were no significant differences due to treatment for total lipid in stomach digesta, or total fatty acid from proximal, mid and distal portion of the small intestine. However, there tended to be a higher fatty acid content in the distal portion of the small intestine with the beef tallow diet, which suggests reduced utilization of this fat.

The results of these studies indicate that the source of fat influences the ability of the young pig to utilize fat supplemented diets. Most investigators theorized that fatty acid chain length and degree of saturation may be the factors causing this differential utilization of fat.

The Effect of Dietary Fat Source on Digestibility of Fat

Variation in fat digestibility in young pigs may be influenced by the dietary lipid. Fat sources with higher digestibility should be a superior energy source for the early weaned pig. Fat digestibility responses in early weaned pigs have been evaluated. However, results of research on digestibility of various animal fat or vegetable fat sources are conflicting. Frobish et al. (1970) demonstrated higher apparent digestibility of fat from diets supplemented with 10 percent lard than from diets supplemented with soybean oil or corn oil. In contrast Sewell and Miller (1965) and Cera et al. (1988a) reported a higher digestibility in pigs fed 8 percent corn oil supplemented than for tallow supplemented diets.

Meaningful conclusions concerning lipid digestibility depend on the use of different methods for fat extraction in the feces and methodology of estimating digestibility. Historically, the solvent extraction method has been used to extract the non polar lipid fraction of feces. Yet, the predominant fraction of fecal lipid (>80%) exists in the form of polar free fatty acids (Hamilton and MacDonald, 1969), which are not completely extracted because of the formation of solvent insoluble fatty acid soap complexes. These unabsorbed fatty acid soap complexes can result in over estimation of fat digestibility (Thurbek and Hancked, 1977).

The most commonly used procedure for determining the digestibility of fat and the individual fatty acids for early weaned pigs has been the fecal index method. This method considers the amounts of specific fatty acids consumed in the diet and voided in the feces (Lloyd and Crampton, 1957; Hamilton and MacDonald, 1969; Sewell and Miller 1965; Cera et al., 1988a, 1989c) but does not take into account the modification of fat metabolism by the microflora in the large intestine (Carlson and Bayley, 1968, 1972; Ozimek et al., 1983). In addition, there is evidence that endogenous fat secretion is diet dependent (Freeman et al., 1968). Thus, a constant correction factor for calculating fat digestibility is doubtful. Therefore feces analysis of fatty acids is of limited application in the study of the digestion and absorption of individual fatty acids since a bacterial hydrogenation can occur in the hind gut.

A digestibility trial was conducted by Li et al. 1989b to investigate the effect of fat sources. Diets had either no added oil (control) or were supplemented with 10% soybean oil, coconut oil or a combination of soybean oil and coconut oil (1:1 ratio).

Pigs were sacrificed at 29 days of age and ileal digestibility was calculated. Cobalt-EDTA, at .2% of the diet, was used as a marker to calculate ileal and total tract nutrient digestibility. There were no differences in apparent digestibility of dry matter, total fat or crude protein; however, pigs fed diets supplemented with 10% fat had higher ($P<.05$) apparent digestibility of total fat than pigs fed the control diet. The apparent digestibility of long chain saturated fatty acid was lower than that of short chain saturated fatty acids, and the apparent digestibility of unsaturated fatty acids was higher than of saturated fatty acids. In a second experiment, Li et al. (1989b) measured the fecal digestibility of total fat and fatty acids in 21 day old pigs. They utilized soybean oil, coconut oil, 50% soybean oil;50% coconut oil, 75% soybean oil;25% coconut oil, and 25% soybean oil;75% coconut oil.

Chromic oxide was used in determination of fat and fatty acids digestibility. The apparent digestibility of the total fat of the diets supplemented with a single fat or combination of fat had higher (P<.03) apparent digestibility than pigs fed the control diets. Apparent digestibility of saturated, long chain fatty acid was lower (P<.05) for pigs fed the diet supplemented with the combination of 75% soybean oil plus 25% coconut oil. The apparent digestibility of unsaturated fatty acids in pigs fed diets containing fat combinations was intermediate between those of pigs fed the diets containing soybean oil and coconut oil.

They suggest that fat digestibility is influenced by chain length and degree of saturation of the fatty acids, with short and medium chain fatty acids being absorbed readily. Endres et al. (1988) conducted a digestibility trial to study the effect of fat source in 28 day old pigs. Diets had either no added oil or were supplemented with 8% fat. Pigs were fitted a T-cannula 5 cm from the ileocecal junction to determine the ileal and fecal digestibility. Dysprosium chloride was added as marker to the diets. Ether extract digestibility from the ileal method was significantly improved with addition of fat. However, dry matter digestibility was lower (P<.05) for pigs fed the fat-supplemented diet compared to pigs fed the control diet. Apparent ether extract digestibilities determined by the ileal collection method were larger (P<.001) than those determined by the fecal collection method.

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

These findings are consistent with the results of Sewell and Miller (1965), who reported that the apparent digestibility of the total lipid fraction of diet containing corn oil was greater ($P<.01$) than diets containing either lard or tallow. These experiments indicated that apparent fat digestibilities and dietary fat absorption increase with either postweaning age or time.

Hamilton and MacDonald (1969) studied the effect of dietary fat source on apparent digestibility of fat and the composition of fecal lipids in 18 day old pigs. The experimental diet contained 10 percent coconut oil, rapeseed oil, lard or tallow. Dietary fat source did not affect apparent digestibility of protein, dry matter or fat. However apparent digestibilities of palmitic (16:0) and stearic (18:0) acids were lower than those of unsaturated or medium-chain saturated fatty acids.

A study by Sewell and Miller (1965) measured the digestibility of individual fatty acids by early weaned pigs. They utilized corn oil, lard and beef tallow substituted for an equal quantity of corn starch and glucose in the basal diet at a level of 8 percent of the total diet. Chromic oxide was used in determination of fat and fatty acid digestibility. The mean absorptions of oleic (18:1) and linoleic (18:2) acids were 98 percent regardless of the type of other fatty acids present in the diet.

The digestibility of the total lipid fraction of the diet containing corn oil was significantly greater than the lipid fraction of the other three diets. There were no significant differences in digestibility of 18:1, 18:2 or 16:0 fatty acids. However, there was a significant decrease in the digestibility of stearic acid (18:0) when compared to either of the other three fat sources. Apparently the absorbability of stearic acid was decreased when fed in combination with high amounts of unsaturated fatty acids. Similar results were found by Hamilton (1969).

A high inverse relationship was found to exist between mean molecular weight (chain length) of the fatty acid of various fats and oils and its apparent digestibility in two week-old pigs (Lloyd and Crampton, 1957). They used chromic oxide to estimate fat digestibility of twenty different fats added individually to a low fat basal ration at the level of 20%. Approximately 30% of the total variation in apparent digestibility was attributed to fatty acid chain length.

Degree of saturation was found to exert minor influences in apparent fat digestibility.

Swiss and Bayley (1976) studied the influence of the degree of hydrolysis of beef tallow on its absorption by pigs at 10 days of age. Beef tallow was hydrolyzed to provide 3, 10, 20, 46, and 100 percent free fatty acids and was fed at a level of ten percent in a semi-purified diet. Tridodecyl glycerol ether was used to estimate fat absorption.

The corrected absorption of the total lipids was between 88 and 93 percent for partially hydrolyzed tallow. Oleic acid was well-absorbed (95 to 99 percent) in all diets. Palmitic and stearic acids were well absorbed in intact and partially hydrolyzed tallow (82 to 84 and 63 to 77 percent, respectively), but digestibility was impaired in completely hydrolyzed tallow.

The amount of fatty acid in the digestive tract was studied in week-old pigs by Carlson and Bayley (1972) using tridodecyl glycerol ether (DGE) as a fat soluble indicator to estimate absorption. These authors postulated that the study of fat digestion based upon dietary intake and fecal output involves at least three interrelated processes: emulsification and absorption of fatty acid in the small intestine, addition of endogenous fat to digesta, and modification of unabsorbable fat residues in the large intestine. One diet was fed with DGE and chromic oxide and one with chromic oxide only as well as a control diet plus chromic oxide. Ten percent beef tallow replaced 10 percent glucose in the experimental diet. Apparent digestibility of fat was significantly lower in pigs fed the beef tallow diet than for those fed the low fat diet.

Different results using chromic oxide and DGE were also observed. DGE did not influence digestibility; therefore, it was accepted as an adequate marker. The calculations based on the ratio of fatty acid to chromic oxide suggest that there was a net secretion of fatty acid into the stomach. Previous observations indicated that this was due to chromic oxide separating from the lipid fraction of the digesta in the stomach and moving into the small intestine ahead of the lipid fraction. Therefore, meaningful absorbability of fatty acids from regions of the digestive tract distal to the stomach could not be calculated with chromic oxide as an absorption indicator. In contrast, DGE showed no change in the amount of fatty acid as the digesta passed through the stomach, but showed a progressive net removal of fatty acid from the digesta in samples taken from successively lower regions of the small intestine.

The portions of saturated acid, palmitic and stearic, were greater in the digesta taken from successively lower regions of the digestive tract indicating a slower removal of the saturated fatty acids from the digesta. These results are consistent with the observations of Carlson and Bayley (1968) who reported low digestibility of stearic acid and high digestibility of oleic and linoleic acid using both conventional and germ-free pigs.

Freman et al. (1968) reported that there is a direct evidence of biohydrogenation of oleic acid in the digestive tract of the piglet using 14C labelled oleic acid. They also showed that the extent of hydrogenation was dependent upon the type of fat in the diet.

The ileal absorbabilities of the fatty acids from beef tallow determined after killing the 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 the feces between the 13th and 23rd day of age. Likewise, Li et al. (1989b) who reported overall the large amount of stearic acid (C 18:0) in the feces as compared to the amount in the ileal digesta resulting in lower apparent digestibility of stearic acid in total tract than that in ileal digesta. Changes in fatty acid composition in the large intestine below the jejunum could be due to the addition of saturated fatty acids in the lower region of the digestive tract or hydrogenation of unsaturated fatty acids associated with microflora of the large intestine. Collection of digesta at the terminal end of the ileum of the small intestine, referred to as ileal digestibility, is considered to give a more accurate estimate of fat digestibility than that provided by fecal collection.

However, there is limited information concerning fatty acid digestibility using illeally cannulated pigs. Ozimek et al. (1983) studied the digestibility of fatty acid on growing pigs. The diets contained 10 percent beef tallow (BT) and rapeseed oil (RO) in a cornstarch-soybean meal-based diet. Pigs were fitted a T-cannula 5 cm from the ileocecal junction to determine the ileal and fecal digestibility of fatty acids. There were no significant differences ($P>.05$) between the ileal and fecal digestibility of fat in beef tallow and rapeseed. 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% (18:0) to 98.8% (18:2) in BT and from 45.8% (C16:0) to 99.6% (C18:2) in RO. The net increase in the level of fat takes place in the large intestine. The increase in the level of saturated fatty acids and decrease in unsaturated fatty acids resulting 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.

Modifications of fatty acids in the 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 digestibilities of individual fatty acids as measures of the extent to which they can be absorbed from different fats by the animal.

The determination of either 'apparent' or 'corrected' digestibility of individual fatty acids in natural foods must be considered of limited usefulness in critical experiments designed to study the factor limiting fatty acid utilization by comparing food intake and fecal output. These results appear to be a result of microfloral activity rather than a direct result of the pig's ability to absorb these fatty acids.

The differences among fat sources in fatty acid composition also affect fatty acid metabolism. Fatty acids with short and medium chain lengths enter the portal blood directly upon absorption (McGarry and Forter 1981) where they are cleared at faster rates and oxidized more rapidly by the liver than are long-chain fatty acids (Bach et al., 1977).

In order to test the differential metabolism of fatty acids Wolfe et al. (1978) studied the effect of age and dietary fat level on fatty acid oxidation in neonatal pigs. Thirty pigs received purified isoenergetic liquid diets containing 2 or 32 percent butterfat (dry matter basis) at 1, 7, or 21 days of age. Five pigs were sacrified two hours post delivery and received no diet. The rate of oxidation of [u-14c] palmitate to Co2 and acid soluble product was measured in homogenates of the liver, kidney, heart or leg muscle. The relative rates of oxidation of [u-14c] myristate (14:0), [u-14c] palmitate (16:0) and [u-14c] stearate (18:0) were measured in homogenates of liver from seven day old pigs. The rate of palmitate oxidation increased with age in liver, kidney and muscle tissue and was maximal at 21 days in kidney and leg muscle tissue and at seven days in liver.

Miller et al. (1971) studied the ability of young pigs to utilize individual fatty acids when differences due to digestion and absorption were eliminated by injecting labelled fatty acids intramuscularly. They reported that lauric (12:0) was oxidized more rapidly than palmitate (16:0). Oxidation rates of 18:1 and 18:0 were not significantly different although a trend toward faster oxidation of 18:1 was observed.

There were no significant treatment effects due to age on fatty acid oxidation or cumulative 14Co2 production observed. However, there was a trend toward faster fatty acid oxidation in the older pigs. 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. Of the four major fatty acids, 18:1 was the most rapidly oxidized, 16:0 and 18:2 were intermediate, while 18:0 was the most poorly oxidized fatty acid.

In general, an inverse relationship between mean molecular weight (chain length) and apparent digestibility has been observed with short chain fatty acids being more efficiently utilized than long chain fatty acids. Unsaturated fatty acids tend to be better utilized than saturated fatty acids. Increasing the degree of hydrogenation of free fatty acids tends to be associated with a decrease in digestibility of the fat.

Effect of Level of Fat on Pig Performance

The effect of fat level in the early weaned pig diet on gain and efficiency is not clearly understood. Allee and Hines (1972) conducted a trial to study the effect of fat level and caloric:protein ratio on pig performance. The fat levels studied included 0, 3, 6, 9, 12 and 15 percent fat with and without adjusting the caloric:protein ratio with increasing levels of fat. With a constant caloric:protein ratio, average daily gain did not differ significantly due to fat level, while feed efficiency and metabolizable energy per unit of gain improved as fat level increased. When the ratio was not adjusted, daily gains decreased and metabolizable energy per unit of gain increased. Cline et al. (1977) conducted a study in which the addition of a corn oil, peanut oil mixture provided 12 to 74 percent of the non-protein calories as fat in isocaloric diets. No differences in rate of growth or cumulative gain were observed. The efficiency of feed utilization improved with an increase in the energy level in the diet. Aherne et al. (1982) reported that the addition of lard to adjusted starter diets improved average daily gain and feed efficiency.

However, the addition of lard to an unadjusted diet led to a slight reduction in feed intake and no improvement in pig performance relative the to control diet, with similar findings reported by Endres et al. (1988). When the caloric:protein ratio is not held constant as fat levels in the diet increases there may be a decrease in pig performance. Eusebio et al. (1965) studied the utilization of lard, tallow, soybean oil and coconut oil when added to the diet at levels up to 38 percent at the expense of equal amounts of other dietary ingredients. In contrast to the results of Cline et al. (1977), an increase in fat level of the diet did not improve feed efficiency, and in general, tended to decrease rate of gain. Specific gravity mesurements of live pigs indicated deposition of fat increased as dietary level of fat increased.

A study conducted by Frobish et al. (1970) indicated that there is a significant quadratic effect of fat level on gain with lard incorporated into the diets at the level of 0, 5 and 10 percent. Frobish's observation was a marked improvement in gain below 0 to 5 percent with a slight decrease in gain above the 5 percent level.

A significant linear improvement in feed efficiency with increasing fat level was also observed. These findings appear to be consistent with results of Peo et al. (1957).

The caloric:protein ratio was not maintained in the studies conducted by Peo et al. (1957) Eusebio et al. (1965) and Frobish et al. (1970) which partially explains why pigs were not able to efficiently utilize the supplemental fat. It appears that when the caloric:protein ratio is held constant with an increased level of fat in the diet, there is an improvement in feed efficiency and no effect on average daily gain. When the ratio is not held constant, there is a decrease in average daily gain and feed efficiency. 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 percent 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 demonstrated not only that the young pig can utilize semi-purified liquid diets high in butterfat but also that the energy from butterfat appears to be used as efficiently as energy from glucose for growth.

Lawrence and Maxwell (1983) conducted a trial to study the effect of fat level with a constant calorie:protein ratio on pigs performance. The fat levels studied were 0, 4, 8 and 12% percent choice white grease. They concluded that efficiency of energy utilization or weight gain did not improve in pigs fed diets that increased fat at a constant calorie:protein ratio. Leibbrandt et al. (1975) observed similar gain of pigs fed diets that increased fat at a constant calorie:protein ratio. Whether or not the early weaned pig is capable of efficiently utilizing fat as a dietary energy source when the calorie:protein ratio is held constant is poorly understood. However, suggestions as to the cause have included protein sources (Owley et al., 1986) and diet form (Frobish et al., 1969). There appears to be a limit to the amount of fat a young pig can efficiently utilize. Also certain fat sources may be more efficiently utilized than others. Since age of pig on trial varied among the experiments summarized, it is also possible that effect of fat level is confounded by the age of the pigs. The consensus in the industry at present appear to indicate that early weaned pigs do not utilize most fat sources very well regardless of calorie protein ratio.

Morphological Development of the Small Intestine in Early Weaned Pigs

Weaning has been shown to cause structural alterations in the small intestines of pigs (Kenworthy, 1976; Miller et al., 1986; Hampson, 1986a; Dunsford et al., 1988). Such alterations include reduction in villus height (an indication of enterocytes destruction), increased depth of the lamina propia (an indication of crypt depth, cellular proliferation and maturity of villus enterocytes). In addition, type or composition of postweaning diet may be partially responsible for the diarrhea and poor performance often observed in early weaned pigs (Cera et al., 1988d; Moore et al., 1988; Hoppe et al., 1989; Li et al., 1989b). Hampson (1986b) suggested that weaned pigs showed a highly significant increase in crypt depth and an increase in the complexity of villus morphology with dramatic reduction in villus height when compared to unweaned pigs. The reduction is small in the intestinal absorptive area and the appearance of a less mature enterocyte population help to explain the increased susceptibility of the pig to diarrhea and "postweaning lag syndrome" in the early weaned pig. When pigs are weaned and abruptly supplied with a dry corn-soybean meal diet, this diet change is associated with a change from the relative high fat, low carbohydrate diet of milk, to the high carbohydrate corn-soybean meal diet.

The basic functional unit of the intestine is the crypt-villus unit. The villi and lamina propia play an important role in the digestion and absorption of nutrients. The cell proliferate in the crypt. Usually each villus is supplied with cells from about tree crypts. At the termination of proliferation in a third of the crypt, differentiation is initiated. Diffentiation is distinguished by morphologic and chemical changes. As a result of this process, the epithelial cell of the villus are endowed with the specific function required for digestion and absorption.

The microvilli size and structure during the immediate postweaning period is also critical to the ability of the young pig to digest and utilize nutrients. Cera et al. (1988d) use electron microscopy (EM) to study small intestine morphology in the young pig. They reported that in the 21 day old pig villi height decreased dramatically and were in close opposition to each other within 3 day of weaning and persisted to day 7 postweaning. After day 7 postweaning, villi height started to increase and lengthened villi morphology were evident by day 14 postweaning. Morphological structure changed from long, finger like projections to longitudinally flattered structure resulting in increase small intestinal surface.

Hoppe et al. (1989) studied the effect of postweaning diet on early weaned pig intestinal morphology and function. Treatments included a simple corn-soybean meal diet and a corn-complex protein and fat diet. They concluded that intestinal morphology and function were not affected by type of diet, but morphology and feed consumption were affected by day postweaning. The change in villus shape corresponded to a trend of less xylose absorbed 5 to 7 day postweaning. Moore et al. (1988) reported that jejunal villus morphology of pigs fed an alfalfa meal diet were characterized by a loss of epithelial cells and microvilli apex, and ileum villi were blunted and frequently folded in pigs fed a 15 percent soybean hull diet. The mechanism by which high fiber intake may impair nutrient absorption is not understood completely. However, studies indicate that chronic intake of dietary fiber decreased intestinal nutrient transport in rats (Freeman, 1984).

The etiology of the structural changes in the small intestines after weaning has not been established. Suggestions as to their causes have included the physiologically damaging effects of fiber in the diet (Moore et al., 1988), damage of the intestinal epithelium can be caused by rotaviruses (Lecce et al., 1982).
Possible cause of change in the piglet small intestine in response to fat source has not been sufficiently studied in the early weaned pig. Li et al. (1989b) studied the effect of various fat sources on gut morphology. Diets either had no added oil (control) or were supplemented with 10 percent soybean oil or coconut oil (1:1 ratio). Pigs were sacrificed at 29 days of age.

Villus height and crypt depth were measured at the midpoint of the small intestine. They reported that pigs fed the combination of soybean oil and coconut oil had longer villus height and rounder villi compared to the pigs fed either soybean oil or coconut oil alone. Whether the longer villi resulted from a suitable proportion of fatty acids for the nutrients requirement of enterocytes is not clear but feed deprivation may depress cell regeneration and migration of enterocytes in the villi. Suggesting that the reduction of the villus height decreased total luminal villus absorptive area and that this may have resulted in inadequate digestive enzyme development or transport of nutrients at the villus surface. The rapid change in small intestinal morphology has been attributed to diet, change in hormone levels, and increased cell proliferation. But none of these studies provide a complete explanation of the effect of diet on performance on early weaned pigs.

If combinations of fat sources cause different histological changes, postweaning, it may be possible to include diets that will minimize or prevent adverse responses. Such diets should result in better performance during the first 10 days after weaning and would be an economic benefit to the swine industry.

CHAPTER III

THE EFFECT OF REPLACING LARD WITH TALLOW ON PERFORMANCE OF EARLY WEANED PIGS

Summary

The effect of increasing the level of tallow at the expense of lard on the performance of early weaned pigs was studied in four replicates utilizing 109 Yorkshire pigs weaned at 21 days of age. The five treatment groups were fed a complex starter diet with 10% fat and differed only in fat source. Diets were 10% lard (T1), 7.5% lard;2.5% tallow (T2), 5.0% lard;5.0% tallow (T3), 2.5% lard;7.5% tallow (T4), 0% lard;10% tallow (T5). Pigs were individually housed in an environmentally controlled feeding room in elevated pens with temperature maintained at 30^{o} and 28.8^{o} C for week 1 and week 2, respectively. Trial length was fourteen days. Estimates of feed intake, body weight and efficiency of feed utilization were obtained weekly, while the apparent availability of dry matter (DM), fatty acids and total fat was estimated from fecal samples collected at the end of the first and second week on trial. All pigs were fed an 18% CP corn-SBM starter diet for an additional 3

week period to evaluate previous treatment effects on subsequent gain and efficiency of gain. During week one pigs fed lard grew more rapidly than those fed 25, 50 and 100% tallow supplemented as a replacement for lard. In contrast pigs fed the 75% tallow replacement had an improved growth rate (6.1%) when compared to pigs fed the lard diet (cubic effect (P<.05). Similar results were observed for period 1 (cubic effect, P<.09). ADG for the subsequent 3 week period (Period 2) was not affected by previous experimental diets.

The effect of substituting tallow for lard at high replacement levels (75% and 100%) improved feed utilization; conversely, feeding lower levels of tallow (25 and 50%) decreased efficiency of feed utilization (cubic effect P<.05). Levels of tallow showed no effect on feed efficiency during the subsequent combined 3 weeks (Period 2).

During week one feed intake tended to increase when lard was replaced by tallow at the 25, and 75% replacement levels. However, a decline in feed intake was observed at the 100% tallow replacement level (Quadratic effect, P<.05). During week 3 a carry over effect from period 1 on feed intake was observed. Pigs fed increasing levels of tallow increased feed intake in period 2 through the 75% substitution level followed by a decreased in the magnitude of the increase at the 100% tallow level (Quadratic effect, P<.05). Feed intake during weeks 4 and 5 were similar among the dietary treatments.

Pigs fed increasing levels of tallow tended to have improved dry matter digestibility although differences were not significant. A linear increase (P<.05) in total fat digestibility with increasing levels of tallow was observed in digestibility estimates determined on day 7. However no differences (P>.10) were observed on day 14. Day 7 fecal digestibility of myristic acid tended to increase with increasing levels of tallow through the 75% substituting level, but a decrease in the magnitude of increase was observed at the 100% tallow level (Quadratic effect P<.05). Increasing the level of tallow supplemented for lard resulted in a linear decrease (P<.05) in digestibility of linoleic acid. Digestibility of palmitic, and oleic on day 7 were not affected by dietary treatments. Fecal fatty acid digestibility of myristic, oleic, and linoleic acid on day 14 was not affected by dietary treatments. However, palmitic and steric acid digestibility linearly decreased (P<.05) with increased level of tallow. An increase in digestibility from day 7 to day 14 was observed for palmitic, steric, oleic, and linoleic acids (P<.05). Digestibility of myristic acid was similar at the two time periods.

This study suggests that fat source can affect performance in early weaned pigs, particularly during the first week postweaning. Further research needs to be conducted in the area of fatty acid availability using ileal canulated pigs.

Introduction

When pigs are weaned as early as 3 weeks of age, they undergo a weaning stress period that is characterized by decreasing gains or weight loss, reduction of feed intake and often diarrhea. Weaning stress can be attributed to a drastic change in diet as well as environment. Since sows' milk is efficiently utilized by pigs and contains 30% fat on a dry matter basis, it has been suggested that feeding diets supplemented with a very high quality fat would reduce weaning problems.

Numerous studies have been conducted to evaluate the effect of addition of animal fat in the diet of early weaned pigs. (Allee et al., 1971; Braude and Newport, 1973; Aherne et al., 1982; Lawrence and Maxwell, 1983; Cera et al., 1988 DeRodas and Maxwell, 1989). Aherne et al. (1982) reported that the addition of lard to a starter diet with an adjusted calorie:protein ratio improved average gain daily and feed efficiency. However the addition of lard to an unadjusted diet led to a slight reduction in feed intake and no improvement in pig performance relative to pigs fed the control diet. Sewell and Miller (1965) reported that the apparent digestibility of the total lipid fraction of a diet containing tallow or lard was similar.

Likewise, Cera et al. (1988a) indicated that pigs fed a tallow supplemented diet performed similarly to pigs fed a lard supplemented diet. Leibbrant et al. (1975) reported that feed efficiency was improved with lard. In a preliminary study, DeRodas and Maxwell (1989) studied the effect of fat addition on starter pig performance by replacing lard with increasing levels of tallow (1-4%). Fat addition for the first two weeks after weaning did not affect ADG, or G:F relative to the diet supplemented with 10% lard. However, contrary to the expected result, there was a linear increase in average daily gain with increasing level of tallow in the diet during the first week, postweaning. Braude 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 pigs.

This study was conducted to compare lard with tallow as a fat source in early weaned pigs and to determined the effect of increasing level of substitution of lard with tallow on performance. Fecal digestibility of dry matter, fatty acid and total fat were also measured.

Material and Methods

A total of 109 pigs were used to study the effect of increasing the level of tallow at the expense of lard on the performance of early weaned pigs. Three replicates with twenty-five pigs in each replicate, and one replicate of 35 pigs were allotted by sex, litter, and weight to one of five dietary treatments after being weaned at approximately 21 days of age, thus providing 22 pigs per treatment. Pigs in replicate 1, 2, and 3 were individually housed in an environmentally-controlled nursery room in elevated metal pens measuring .61 m by 1.1 meters, while pigs in replicate 4 were individually housed in an environmentally-controlled nursery room in elevated metal pens measuring .47 m by .76 meters. The room temperature was maintained at 31° C during the first week and decreased 1° C per week for the remainder of the experiment.

During the first 14 days (period 1), the pigs were assigned to one of five dietary treatments (Table 3.1). Diets were a complex starter diet containing 10% fat and differed only in fat source. Treatments were 10% lard (T1), 7.5% lard; 2.5% tallow (T2), 5.0% lard; 5.0% tallow (T3), 2.5% lard; 7.5% tallow (T4), 0% lard; 10% tallow (T5).

Pigs had ad libitum access to feed and water. During the first and second week, chromic oxide was added to each diet at the rate of .25% to provide an indigestible marker for determining nutrient digestibility.

Calculated analysis of each diet is presented in table 3.2. All diets were formulated to contain 1.40% lysine, 0.90% Ca and 0.70% P. In the subsequent 21 day period (period 2), all pigs were fed an 18% CP corn-SBM starter diet (Table 3.3) to determine carry-over effects from period 1. During the 5 week trial, individual pig weight was recorded, feed intake was mesured and feed efficiency (G:F) was evaluated weekly. Protein, moisture and ether extract of feed and feces were determined according to the AOAC

(1980). Feed samples were collected in pans directly under individual feeders, dried and standardized to 90% dry matter in order to more accurately estimate feed intake.

Fecal samples were collected from each pig on the last 2 days of the first and second week from each pen in replicate 4 and immediately frozen and stored at -20^{o} C. These samples were dried at 100^{o} C for 24 hours and ground through a 1 mm screen to ensure uniform distribution of chromic oxide. Chromic oxide was determined by the atomic absorption spectrophotometer method (Williams et al., 1962).

Fatty acid composition of fat sources used in diets is presented in table 3.4 and table 3.5. Methyl esters of the fatty acids of the dietary and fecals fats were prepared by adding 4.0 ml sodium-dried benzene, 0.4 ml DMP2, 2-Dimethoxypropane, and .5 ml MeOH-HCl Metholic HCl to the fat sample. This was dried under nitrogen condition and then diluted with sodium dried-benzene (Lawrence and Maxwell, 1983). Methyl esters were separated on a crosslinked Methyl silicone gum 12 m * 0.2 mm * 0.33 um film thickness column in a gas-liquid chromatographic column instrument with a flame. The ionization detector operated at 270^{o} C and an inlet temperature of 200^{o} C. Identification of fatty acid methyl ester was made by comparison with known standards as mixture references (GLC Alltech Associates, Inc., Deefield, IL 60015). Temperature program was 115^{o} C -215^{o} C at 4 C/min. The apparent fecal availability of DM was calculated using chromic oxide as the indigestible marker.

In week one of the first replicate, one pig died due to unknown causes. Also one pig in replicate 1, two pigs in replicate 2 and one pig in replicate 4 were not considered in the analysis of week one feed efficiency. They were removed because of large negative G:F ratios, which may have been caused by a diarrhea problem even though feed intake was positive.

Data for each response criterion were analyzed by the least squares analysis of variance. The model for average daily gain (ADG), feed efficiency (G:F) and average daily feed intake (ADFI) included the main effects of experiment replication, treatment, sex, and litter within replicates and the appropriate interactions (Treatment (T) * Sex (S), T * Replication (REP), REP * S and T * S * REP). Initially the full model was used in the analysis; then effects with probability greater than .20 were excluded, and the data was analyzed with the reduced model. The model used for dry matter, fatty acid and total fat digestibility included the main effect of treatment, sex, week and the treatment * week intereaction.

Orthogonal polynomial contrasts were used to test for linear, quadratic, cubic and quartic changes in response to the different levels of tallow.

Results and Discussion

The effect of replacing lard with tallow on ADG during the 14d experimental period (Period 1) and the subsequent 3 week period (Period 2) is shown in table 3.6. During week one pigs fed lard (Treatment 1) grew more rapidly than those fed diets with tallow replacing 25, 50 and 100% of the lard (Treatments 2, 3 and 5 respectively). The decrease in gain was 22.0, 13.7 and 29.9% respectively, in pigs fed diets with 25, 50 and 100% replacement of tallow for lard when compared to those fed the lard diet (Treatment 1). In contrast to this decrease in gain, pigs fed a diet with 75% replacement of tallow for lard (Treatment 4) grew 6.1% faster than pigs fed the lard based diet (Treatment 1). This growth response to increasing level of tallow supplemented as a replacement for lard resulted in a significant cubic effect ($P<.05$). During the second week, ADG was not significantly affected by dietary treatment.

Average daily gain for period 1 (0-14d) was similar to the results observed during week one. ADG decreased in pigs fed diets with 25, 50 and 100% replacement of lard with tallow (treatments 2, 3 and 5) and tended to increase in pigs fed the diet with 75% replacement of lard with tallow (Treatment 4) when compared to pig fed the lard diet (Treatment 1). The magnitude of difference, however, was lower than those observed during the first week but still resulted in a cubic effect which approached significance

(P<.06). During week 3 (period 2), feeding increased levels of tallow in period 1 resulted in an improvement in subsequent ADG in pigs fed all the tallow containing diets. Pigs fed diets with 25 and 50% replacement of lard with tallow (Treatments 2 and 3) had the largest relative increase when compared to pig fed a lard based diet (Treatment 1) followed by a trend for a decrease in magnitude of the response at higher levels of tallow substitution (Treatment 4 and 5). ADG in pigs fed the 25 and 50% tallow replacement diets increased by 17.5 and 19.5% respectively, when compared to those fed the lard based diet, whereas pigs on fed the 75 and 100% tallow replacement diets had a 12.6 and 8.76% increase, respectively when compared to pigs fed the lard diet (Treatment 1). These changes in responses to increasing levels of tallow supplemented as a replacement for lard resulted in a quadratic effect (P<.06). During week 4 and 5 ADG was not significantly affected by dietary treatments. During the subsequent combined 3 week period (period 2, 14-35d) ADG response to increasing levels of tallow supplementation was similar to that observed in week 3. ADG increased by 11.2, 6.5, 5.6 and 4.5% respectively in pig fed diets with 25, 50, 75 and 100% replacement of lard with tallow when compared to those fed the lard base diet (Quadratic effect, P<.08). Efficiency of gain (G:F) during the 14d experimental period (period 1) and the subsequent 3 week period (period 2) are presented in table 3.7. During week one pigs fed the 75 and

100% tallow replacement of lard diets (Treatments 4 and 5) had a higher gain to feed ratio (G:F) than those fed the lard diet (Treatment 1). The magnitude of the increase G:F was 16.8 and 7.70 % respectively in pigs fed diets with 75 and 100% replacement of tallow for lard when compared to those fed the lard diet (Treatment 1). However, G:F in pigs fed diets with 25% and 50% replacement of lard with tallow (Treatments 2 and 3) decreased by 7.8 and 2.4% when compared to pigs fed the lard based diet (Treatment 1). These changes in G:F with increasing tallow supplemented as a replacement for lard resulted in a significant cubic effect (P<.05). During week 2, and for the overall 14d experimental period (Period 1) G:F was similar among the dietary treatments. Efficiency of feed utilization during week 3 (period 2) was also not significantly affected by previous experimental treatment. During week 4, however, pigs previously fed 25, 50, 75 and 100% tallow replacement for lard (Treatments 2, 3, 4 and 5, respectively)) had a 5.9, 12.3, 7.5 and 2.8% decrease in G:F, when compared to those fed the lard based diet (Treatment 1). This response resulted in a quadratic effect which approached significant (P<.06). G:F during the combine subsequent 3 week period (Period 2, 14-35d), tended to improved at lower levels of substitution of lard with tallow followed by a decline in G:F at higher levels of substitution when compared to pigs previously fed lard based diet resulting in a cubic effect which approached significance (P<.09).

The effect of replacing lard with tallow on average daily feed intake (ADFI) for the 14 day experimental period (Period 1) and the subsequent 3 week period (Period 2) is presented in table 3.8. Increasing levels of tallow during the first week tended to increase feed intake in pigs fed diets with 25, 50 and 75% replacement of lard with tallow (Treatments 2, 3 and 4) followed by a decline in intake at the 100% substitution level (Treatment 5) when compared to pigs fed the lard based diet (Treatment 1). Pigs fed diets in which tallow replaced 25 and 75% of the lard consumed 7.2% and 6% (Treatment 2 and 4, respectively) more feed than those fed the lard based diet (Treatment 1), whereas pigs fed 50 and 100% tallow (Treatment 3 and 5) consumed 3.4 and 23.1% less, respectively than pigs fed the lard based diet (Treatment 1). This resulted in a significant quadratic response ($P<.05$). During week 2, there was no consistent change in ADFI with increasing level of tallow substitution, however, pigs fed 50 and 100% tallow (Treatment 3 and 5) comsumed less feed than those fed lard or the 75% tallow replacement diet (Treatment 1 or 5, respectively). ADFI in pig fed the 25% tallow diet (Treatment 2) was intermediary. Pigs on treatments 2 and 4 consumed 8.7% and 13.5% more feed when compared to pigs fed the lard supplemented diet (Treatment 1) and pigs on treatment 3 and 5, consumed 7.3 and 10.4% less feed, respectively when compared to pigs on treatment 1. Even with these differences, neither the linear nor the quadratic component for the second week were significant. Average daily feed intake (ADFI) for the overall 14 day experimental period (period 1), followed a similar trend as that observed for week one, with increased feed intake at the 25, 50 and 75% replacement of lard with tallow (Treatment 2, 3 and 4) when compared to pigs fed the lard based diet (Treatment 1) followed by a decline at the 100% tallow level (Treatment 5; Quadratic effect P<.05)). During week 3(period 2), pigs previously fed diets with 25, 50, 75% and 100% replacement of lard with tallow in period 1 (Treatments 2, 3, 4 and 5) increased feed intake, when compared to pigs fed the lard based diet (Treatment 1). Pigs consumed 13, 15, 16.6 and 10% (treatment 2, 3, 4 and 5, respectively) more than those fed the lard based diet (Treatment 1). This resulted in a significant quadratic response (P<.05). Average daily feed intake during week 4, 5 and the combine 3 weeks period (period 2) was not significantly different among pigs regardless of the previous experimental diets.

The apparent fecal availability of dry matter and total fat on day 7 and day 14 of the experimental period is shown in table 3.9. Apparent fecal digestibility of dry matter was not affected by replacement of lard with tallow in samples obtained on day 7 or day 14. Pigs fed increasing levels of tallow (Treatments 2, 3, 4 and 5) tended to improved dry matter digestibility when compared to those fed the lard based diet (Treatment 1), however, differences were not significant.

In samples obtained on day 7 total fat digestibilities in pigs fed increasing levels of tallow supplemented as a replacement for lard (Treatments 2, 3, 4 and 5) had a 5.8, 9.2, 17.0, and 11.22% increase in digestibility when compared to fat digestibility in pigs fed the lard supplemented diet (Treatment 1, linear effect, P<.05). In samples obtained on day 14 the total fecal digestibility of fat was similar among the dietary treatments. The effect of replacing lard with tallow on fecal digestibility of fatty acids in samples obtained on day 7 and day 14 of the experimental period is shown in table 3.10. Apparent digestibility of C:14 (myristic) increased with increasing level of tallow from 0 to 7.5% tallow (Treatments 1, 2 and 3) followed by a decrease in the magnitude of response beyond the 7.5% substitution level of lard (Quadratic effect, P<.05). Fecal digestibility of palmitic (C 16:0), stearic (C 18:0) and oleic (C 18:1) was not affect by dietary treatment, however, for linoleic (C 18:2), there was a linear decrease (P<.05) with increasing level of tallow at expenses of lard. Fecal fatty acid digestibility in samples obtained on day 14 were not affected by dietary treatments for C 14:0, C 18:1 and C 18:2. However for C 16:0 and C 18:0, there was a linear decrease (P<.05) with increasing level of tallow supplemented as a replacement for lard.

Differences in apparent fecal fatty acid digestibility between day 7 and 14 are presented in table 3.11. Differences in estimates of fatty acid availability from samples obtained on day 7 and day 14 were observe for C 16:0, C 18:0, C 18:1 and C 18:2 (P<.05) with a general increase in digestibility between day 7 and 14. Myristic digestibility from day 7 to 14 tended to decrease with increasing levels of tallow from 0 to 7.5% tallow (Treatment 2, 3 and 4), followed by an increase in digestibility between day 7 and 14 in pigs fed the 10% tallow diet (Treatment 5, Quadratic effect P<.05). Estimates of differences were not affected by dietary treatment for C 16:0, C 18:0 and C 18:1, however for C 18:2 there was a linear increase (P<.05) with increasing levels of tallow at the expenses of lard.

Based on the growth performance data, replacement of lard with tallow in early weaned pig diets indicated that replacement of 75% lard with tallow tended to promoted greater and more efficient gain relative to diets supplemented with 100% lard, 75% lard;25% tallow, 50% lard;50% tallow or 100% tallow during first week postweaning. Similar results were reported by DeRodas and Maxwell (1989) who observed that an increasing level of tallow (1-4%) resulted in a linear increase (P<.08) in performance during the first week postweaning in a preliminary study. Tallow and lard had approximately 35% saturated fatty acid and 65% unsaturated fatty acid with a chain lengths of 16 or more carbons and differ only in that tallow has approximately 74% more stearic acid than lard, and stearic is consider to be poorly hydrolyzed (Sewell and

Miller, 1965; Hamilton and MacDonal, 1969; Carlson and Bayley, 1972;) and oxidize (Wolfe et al., 1978; Boyd et al., 1982) by the young pig. In this study lard which contain low amounts of steric acid, was not utilize as efficiently as the replacement of 75% lard for tallow. Steric acid is apparently not the only factor limiting utilization, since the combination of 75% tallow replacement of lard which contain about 35% more steric acid relative to lard supplemental diet was utilized more efficiently. None of the lipid provided as the sole lipids source resulted in response that was superior to the combination of 75% tallow replacement of lard. Pigs fed either lard or tallow as a single supplemental fat source had a similar ADG and G:F. Sewell and Miller (1965) and Cera et al. (1988b) also found no difference in performance between pigs fed lard or tallow supplemented diets.

The mechanism by which the combination of 2.5% lard with 7.5% tallow improves performance cannot be determined from the present study, but a number of possibilities exist. Li et al (1989) reported that pigs performed better on diets containing the combination soybean oil (50%) and coconut oil (50%) than on diets containing either of the oils alone. In a second study, Li et al. (1989b) investigated the effect of soybean oil, coconut oil, or a combination of these fat sources on ileal digestibility and morphology of the small intestine. Results indicated that pigs performed better on diets containing the combination 50% soybean oil and 50%

coconut oil and had longer and rounder villi compared to those fed soybean oil or coconut oil alone. Pigs fed the diet with added soybean oil or coconut oil alone had shorter and more slender villi. Cera et al. (1988) suggested that jejunal villi remained shorter during the postweaning period when dietary fat was fed, implying a reduced absorptive area.

The apparent digestibility of either total lipid or dry matter in this study did not differ with age. Similar results were reported by Hamilton and McDonald (1969) Braude and Newport (1973) who observed similar fat digestibility at 2 to 3 d vs 26 to 31 d postweaning. Frobish et al. (1970) also found no difference in fat digestibility between pigs at 10 and 28 days postweaning. In contrast Lloyd et al. (1957) and Cera et al. (1988a) reported significant improvement in fat digestibility in pigs between 3 and 7 weeks of age. Part of the differences between these studies may be associated with several factors. Factors which might affect fat digestibility determination is the methods used to extract the fecal lipid and the time periods tested. Wilson and Leibholz. (1979) indicated lower tallow digestibility when pigs were fed protein from soybean meal compared with protein from milk. Apparent digestibility was relative high for all fatty acids, except for stearic acid. Stearic acid is consider to be poorly hydrolyzed (Sewell and Miller, 1965; Hamilton and MacDonal, 1969; Carlson and Bayley, 1972) and oxidize (Wolfe et al., 1978; Boyd et al.,

1983) by the young pig. Poor utilization of long-chain saturated fatty acids appears to be associated with faulty absorption of these fatty acids. 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. Utilization of long chain saturated fatty acid tended to improved with the age of the animals. This is shown by the higher apparent digestibility of palmitic and steric at 35 day of age for the groups fed the two fat sources. Hamilton (1969) reported similar results. This suggests that efficiency of fatty acid utilization by the early weaned pig, particularly for long chain fatty acids, appear to increase with age.
In general, the results of this study indicate that increasing the level of substitution of lard with tallow had a slight advantage over lard, which is contrary to the hypothesis that steric acid decreased utilization.

Further research should be conducted in the area of fatty acid availability using illeal cannulation. In addition, gut morphology studies of the small intestine to further enhance the understanding of the effect specific of fatty acid combination diets in the early-weaned pig are necessary before the utilization may be predicted from 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
Lard[b]	10.00	7.50	5.00	2.50	0.00
Tallow[b]	0.00	2.50	5.00	7.50	10.00
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 riboflavin, 7.3 mg menadione, 0.4 mg Vitamin b12, 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)

Ingredient	Diets[a]				
	1	2	3	4	5
Calculated analysis					
Crude protein	19.67	19.67	19.67	19.67	19.67
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
Calcium	.90	.90	.90	.90	.90
Phosphorus	.70	.70	.70	.70	.70
M.E. (kcal/kg)	3681.70	3681.70	3681.70	3681.70	3681.70
Actual analysis					
Crude protein (N x 6.25)	20.37	19.13	20.41	20.45	20.26
Ether extract	17.04	16.37	18.84	17.81	16.89

[a]As fed basis

TABLE 3.3

FATTY ACID COMPOSITION OF LARD AND TALLOW

Fatty Acid %[a]	Lard	Tallow
C12[b]:0[c]		0.5
C 14:0	1.59	2.80
C 16:0	23.62	25.70
C 18:0	10.28	17.58
C 18:1	51.64	43.47
C 18:2	12.87	9.95

[a]Fatty acid mehyl esters were separated on a crosslinked Methyl silicone gum 12m x 0.2mm x 0.33um film thickness column in a Hewlett Packard 5890_A gas-chromatograph equipped with a flame ionization detector operated at 270°C and an inlet temperature of 200°C. Temperature program 115 - 213°C at 4.0°C/min.

[b]Number of carbon atoms in fatty acid.

[c]Number of double bonds in fatty acid.

TABLE 3.4

FATTY ACID COMPOSITION OF DIETS

Fatty Acid %[a]	DIETS 1	2	3	4	5
b c					
C 14:0	1.57	1.89	2.36	2.72	2.62
C 16:0	23.70	23.40	23.29	25.47	23.99
C 18:0	12.12	13.75	14.98	18.74	16.16
C 18:1	41.72	42.22	41.41	41.28	43.15
C 18:2	20.87	18.66	18.02	11.79	14.08

[a]Fatty acid mehyl esters were separated on a crosslinked Methyl silicone gum 12m x 0.2mm x 0.33um film thickness column in a Hewlett Packard 5890_A gas-chromatograph equipped with a flame ionization detector operated at 270°C and an inlet temperature of 200°C. Temperature program 115 - 213°C at 4.0°C/min.
[b]Number of carbon atoms in fatty acid.
[c]Number of double bonds in fatty acid.

TABLE 3.5

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 3.6

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

Item	TREATMENTS				
	1 10% Lard	2 7.5% Lard 2.5% Tallow	3 5.0% Lard 5.0% Tallow	4 2.5% Lard 7.5% Tallow	5 10% Tallow
No. of Pigs	21	22	22	22	22
Period 1					
d0-7[b]	237.08	194.26	208.56	252.55	182.51
d7-14	297.89	334.66	288.74	326.83	290.54
d0-14[c]	281.92	267.21	248.59	298.16	247.21
Period 2					
d14-21[d]	353.18	428.12	438.98	404.13	387.08
d21-28	542.67	584.36	525.47	530.30	523.97
d28-35	622.78	699.50	651.81	653.76	641.50
d14-35[e]	504.69	567.99	539.62	534.80	528.35

[a]LS means
[b]Cubic effect (P<.01)
[c]Cubic effect (P<.06)
[d]Quadratic effect (P<.06)
[e]Quadratic effect (P<.08)

TABLE 3.7

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

Item	TREATMENTS				
	1 10% Lard	2 7.5% Lard 2.5% Tallow	3 5.0% Lard 5.0% Tallow	4 2.5% Lard 7.5% Tallow	5 10% Tallow
No. of Pigs	21	22	22	22	22
Period 1					
d0-7[b]	.84	.78	.82	1.01	.91
d7-14	.70	.77	.82	.70	.79
d0-14	.81	.73	.78	.80	.79
Period 2					
d14-21	.68	.75	.74	.65	.67
d21-28[c]	.73	.69	.65	.68	.71
d28-35	.66	.69	.65	.64	.66
d14-35[d]	.69	.71	.67	.66	.68

[a]LS means g gain/g feed
[b]Cubic effect (P<.05)
[c]Quadratic effect (P<.06)
[d]Cubic effect (P<.09)

TABLE 3.8

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

Item	1 10% Lard	2 7.5% Lard 2.5% Tallow	3 5.0% Lard 5.0% Tallow	4 2.5% Lard 7.5% Tallow	5 10% Tallow
	TREATMENTS				
No. of Pigs	21	22	22	22	22
Period 1					
d0-7[b]	264.10	284.69	255.36	280.92	214.53
d7-14	416.48	456.21	388.17	481.34	377.35
d0-14[b]	340.29	370.45	321.76	381.13	295.94
Period 2					
d14-21[b]	491.04	564.52	577.69	589.04	546.90
d21-28	798.74	844.74	821.57	793.83	788.45
d28-35	961.76	1040.43	1026.75	1022.61	994.91
d14-35	758.39	818.24	813.49	801.96	783.14

[a]LSmeans
[b]Quadratic effect (P<.05)

TABLE 3.9

THE EFFECT OF REPLACING LARD WITH TALLOW ON DRY MATTER AND TOTAL FAT DIGESTIBILITY BY THE EARLY WEANED PIG AT PERIOD (1).

	TREATMENTS				
Item	1 10% Lard	2 7.5% Lard 2.5% Tallow	3 5.0% Lard 5.0% Tallow	4 2.5% Lard 7.5% Tallow	5 10% Tallow
Pig per treatment No.	5	5	5	5	5
Apparent Digestibility:					
Dry matter %					
d-7	77.74	78.60	80.78	82.02	78.47
d-14	78.52	76.86	79.35	81.88	78.07
Total Fat %					
d-7 [b]	70.89	75.32	78.07	85.49	79.85
d-14	78.26	74.63	82.89	81.40	82.43

[a]Lsmeans
[b]Linear effect (P<.05)

TABLE 3.10

THE EFFECT OF REPLACING LARD WITH TALLOW ON FECAL FATTY ACID DIGESTIBILITY IN THE EARLY WEANED PIGS ON DAY 7 AND DAY 14.

Item	Treatment				
	1 10% Lard	2 7.5% Lard 2.5% Tallow	3 5.0% Lard 5.0% Tallow	4 2.5% Lard 7.5% Tallow	5 10% Tallow
Pig per treatment No.	5	5	5	5	5
<u>Fatty acid</u>					
C 14:0[a]					
d 7[b]	75.20	80.34	82.74	84.79	75.94
d 14	80.27	83.07	85.97	83.47	80.32
C 16:0					
d 7	76.59	79.20	76.13	75.83	75.69
d 14[c]	98.55	98.51	98.39	98.40	97.43
C 18:0					
d 7	48.35	70.15	56.14	62.76	57.58
d 14[c]	98.57	98.55	98.49	98.27	97.59
C 18:1					
d 7	95.18	87.99	92.54	88.57	91.49
d 14	97.51	98.57	97.93	97.65	97.08
C 18:2					
d 7[c]	81.84	86.44	86.65	66.90	73.93
d 14	98.88	97.10	97.71	98.09	96.74

[a]No of carbon atoms:No of double bonds
[b]Quadratic effect ($P<.05$)
[c]Linear effect ($P<.05$)

TABLE 3.11

DIFFERENCE OF APPARENT FECAL FATTY ACID AVAILABILITY ESTIMATES BETWEEN DAY 7 AND DAY 14 IN THE EARLY WEANED PIG.

Item	Treatment				
	1 10% Lard	2 7.5% Lard 2.5% Tallow	3 5.0% Lard 5.0% Tallow	4 2.5% Lard 7.5% Tallow	5 10% Tallow
Pig per treatment No.	5	5	5	5	5
Fatty acid					
C 14:0[ab]	5.10	2.72	3.23	-1.32	4.38
C 16:0	21.97	19.30	22.30	22.56	21.74
C 18:0	50.21	28.40	42.35	35.51	40.00
C 18:1	2.33	10.38	5.38	9.07	5.59
C 18:2[c]	16.03	10.66	11.05	31.19	22.81

[a]No of carbon atoms:No of double bonds.
[b]Quadratic effect (P<.05).
[c]Linear effect (P<.05).

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