# UTILIZATION OF FAT
# BY YOUNG PIGS

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# CHAPTER I

## INTRODUCTION

Only limited research has been conducted to determine the nutritional requirements of the neonatal pig due primarily to the difficulty in developing a system which would result in a high survival rate of the pigs and promote growth at a rate approaching that supported by the sow under normal rearing systems. The recent development of techniques for the routine removal of pigs by cesarean section, rearing under Specific Pathogen Free (SPF) conditions and the development of soluble semipurified diets which will support adequate survival and growth suggests that such studies are possible. Neonatal pigs reared under these conditions make an ideal model for studying nutritional requirements with minimal influence of such non-nutritional factors as litter size, age of dam, environmental temperature, mechanical injury and pathogenic organisms.

Several changes in the swine industry make the development of dietary regimes for the non-maternal rearing of baby pigs necessary. Larger, more specialized commercial swine units can justify the establishment of a nursery for orphan pigs, excess pigs from large litters and those being crowded out of position in the nursing line or for pigs from sows with agalactia after farrowing. Likewise, it is now feasible in large confinement swine operations to practice early weaning of litters farrowed out of sequence for maximum utilization of farrowing facilities or in cases where variation in conception rate results in more bred sows than the existing farrowing facilities can accomodate. All of these developments could save substantially on the 20 to 25 percent sow related death losses of pigs that now occur between birth and weaning and make a significant contribution to more efficient swine production.

Since sow's milk contains approximately 30 percent fat on a dry matter basis and most diets available for artificially reared pigs contain only 10 percent fat, fat utilization by the neonatal pig is an area that should be more thoroughly investigated. Results of studies conducted at Oklahoma State University suggested that dietary butterfat fed up to 32 percent fat on a dry matter basis resulted in increased weight gains and greater dietary consumption. The effect of other dietary fats fed at this high level have not been determined and require further investigation. In addition, previous results have indicated that certain fatty acids may be preferentially utilized by the neonatal pig suggesting differential utilization of dietary fat depending upon fat source.

When pigs are weaned, they undergo a weaning stress period that is characterized by decreased gains or weight loss and increased death rate. This is especially apparent in early weaned pigs. Weaning stress has been attributed to a drastic change in diet as well as environment. Adding fat to the starter ration may help alleviate weaning stress by increasing the palatability and utilization of the ration. Much research has been conducted in this area, but data fail to agree. Whether fat should be added to the starter ration and at what level needs further investigation. It is of interest to the swine industry to see if adding fat will reduce the weaning lag and result in faster growing, more efficient pigs.

# CHAPTER II

# REVIEW OF LITERATURE

## Introduction

Sow's milk contains approximately 30 percent fat on a dry matter basis (Perrin, 1955; deMan and Bowland, 1963). Pigs perform well on their mother's milk and this would suggest that young pigs are capable of utilizing a high fat diet. At birth, the fat content of the pig is approximately 1.5 percent and increases by 14 days of age to 15 percent (Manners and McCrea, 1962). It has been hypothesized (Friend, 1974) that since the neonatal pig has such a propensity to store fat, it will have a parallel ability to metabolize it. Very little research has been conducted to evaluate the ability of the neonatal pig to utilize supplemental fat.

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 and abruptly supplied with a dry corn-soybean meal diet, a period of poor performance commonly referred to as the "weaning lag syndrome" occurs (Mersmann et al., 1973; Okai et al., 1976). A major change in dietary components with conventional rations results in a drastic reduction in fat intake since sow's milk is approximately 30 percent fat on a dry matter basis and most common corn-soybean meal diets are approximately two to three percent fat. It has been suggested that increasing the level of a high quality, unsaturated fat in the early weaned pig diet may help alleviate this early weaning problem.

Much research has been conducted in this area to compare levels as well as source and form of added fats, however, data fail to determine if the young pig is capable of utilizing fat calories as efficiently as carbohydrate calories. The interpretation of results has been complicated by different methods of adding fat to the ration, varying sources and levels of fat as well as differences in age and handling of the pigs.

## Fat Utilization by the Neonatal Pig

Mach and Princ (1968) conducted a trial to determine the primary energy source in nursing pigs. The energy balance of 34 piglets whose nutrient supply was provided by controlled nursing was observed with an indirect method of calorimetry. The quantity of oxidized fat and glucides with the correction of catabolized proteins for 24 hours was calculated. This study indicated that the primary energy source of suckling piglets was fat. Fat provided approximately 94 percent of the energy during the colostrum phase decreasing to 68 percent by six weeks of age.

Wolfe et al. (1977) studied the effect of level of butterfat in a liquid diet on the performance of pigs from zero to 14 days of age. Butterfat replaced glucose in isoenergetic, liquid, semipurified diets. 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 demonstrate not only that the neonatal pig can utilize semi-purified liquid diets high in butterfat, but also that energy from butterfat appears to be used as efficiently as energy from glucose for growth purposes.

Schendel and Johnson (1953) conducted a trial to study the effect of the addition of aureomycin and lard on baby pigs raised on dried skim milk diets. When the skim milk basal ration and the basal ration plus 30 percent lard were compared, the high fat diet greatly improved feed efficiency ratios in pigs weaned from their dam at 48 hours. However, there was no significant treatment effect on observed final weight and final weight adjusted for variation in initial weight.

Catron et al. (1953) conducted a series of experiments to develop practical synthetic milk formulas for baby pigs. The dietary treatments in the first experiment included a basal dried skim milk ration, basal plus lard, basal plus casein and basal plus lard and casein. The pigs were taken from their dams immediately after farrowing and before obtaining colostrum and placed on trial. The experimenters were not successful in raising pigs that had not received colostrum without a dietary source of fat. The growth rate of pigs on the lard-dried skim milk diet and those on the lard-casein-dried skim milk diet were similar. A 3 x 3 factorial experiment was conducted utilizing three levels of lard (10, 20 and 30 percent) and three levels of solids (15, 20 and 25 percent). The average age of pigs on trial was three days and all pigs received colostrum. Pig starter was offered at the end of two weeks on trial but the milk ration was the only ration for the first two weeks. There were no significant treatment differences in live weights during the first two weeks. The efficiency of the rations tended to decrease as both fat and solids increased. Decreasing the fat content of the milk significantly increased the final (eight weeks of age) pig weights but did not affect feed efficiency. Of the 10, 20 and 30 percent fat levels, the lowest level produced the best growth.

The ability of the neonatal pig to utilize fat as an energy source is not clearly understood. There are many factors that may influence the ability of the young pig to efficiently utilize fat including type and level of fat as well as fatty acid composition, age of pig and particle size. Confounding of these factors in the data presented in the literature complicates interpretation of data pertaining to the ability of the neonatal pig to utilize fat.

The ability of the young pig to utilize a ration high in fat may be partially dependant upon the type of fat included in the diet. Braude and Newport (1973) studied the effects of replacing butterfat in a whole-milk diet by 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 fats 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 lipids in stomach digesta or total fatty acids from proximal, mid and distil portions of the small intestines. However, there tended to be a higher fatty acid content in the distil portion of the small intestines with the beef tallow diet which suggests poorer utilization of this fat.

In a second trial conducted by Braude and Newport (1973), different proportions of beef tallow or soybean oil and dried skin milk in the diet did not improve live weight gain, feed efficiency or nitrogen retention in response to an increase in energy resulting from an increase in the proportion of fat in the diet. Live weight gain tended to be lower in pigs fed the beef tallow diet than in those fed soybean oil and the control diet. The fatty acid content of digesta in the small intestines was greater with beef tallow indicating that it was more poorly utilized than soybean oil. There was an increase in fat and a decrease in protein content in the carcass when the proportion of fat in the diet was increased. The absence of response to the increased dietary energy levels may have been due to the accompanying decrease in protein content of the higher fat diets as fat was added to the diet at the expense of dried skim milk. To determine if the decrease in protein content influenced the performance of the two to 28 day old pig, Braude et al. (1976) conducted a third trial in which the levels of soybean oil, protein and methionine were varied. In experiment one, the basal diet contained dried skim milk and soybean oil. An increased level of soybean oil was added at the expense of dried skim milk in diet two and in diet three casein was added to maintain a similar level of protein in the high fat diet as compared with the basal diet. Each diet was fed with and without added methionine. Increasing the level of fat did not alter performance except for marginally lower weight gains when crude protein was reduced. Methionine supplementation had no effect. In experiments two and three, different levels of fat and protein were studied by varying the levels of dried skim milk, soybean oil and casein. In experiment two live weight gains were reduced when fat and crude protein levels increased, however, these results were confounded by large differences in intake. In experiment three, more equal feed consumption was obtained by feeding 25 percent less liquid diet. The level of fat did not significantly effect weight gain or feed to gain but there was a significant reduction in weight gain at the higher protein level. Carcass lipid content increased with increased levels of added fat.

The experiments conducted by Braude and Newport (1973) and Braude et al. (1976; 1977) indicated that increasing the level of fat in the diet does not significantly improve weight gain or feed efficiency, however, carcass lipid content is increased. A greater protein requirement was found when feeding a diet high in fat. Reduction in weight gain may result depending on the type of fat incorporated into the diet as exemplified by the beef tallow treatment. The fatty acid content of the small intestines was greater in pigs fed beef tallow as the fat source indicating poorer utilization of this fat. Pigs fed soybean oil performed as well as those fed butterfat. The performance of pigs fed butterfat was slightly better than those fed coconut oil and greatly superior to those fed beef tallow.

Type of fat incorporated into the diet appears to influence fat utilization by the pig. This could be attributed to fatty acid composition of the fats and may be the result of differential fatty acid metabolism in the neonatal pig. Seerley and Poole (1974) conducted a trial to study the effect of prolonged fasting on carcass composition, blood fatty acids and glucose in neonatal swine. The four treatment groups from each litter included: one pig killed at birth (newborn), one pig allowed to nurse three days then killed (3 day fed), two pigs fasted for three days (3 days fasted) and four pigs allowed to nurse until one week of age and then subjected to the same treatments as newborns (7 day old, 10 day fed and 10 day fasted, respectively). Percent myristic (14:0), palmitoleic (16:1), stearic (18:0) and arachidonic acid (20:4) were significantly less in 3 day fed than at birth. The only significant increase in fatty acid concentration was linoleic (18:2). The 3 day fasted group had significantly lower percentages of 14:0, 16:0 (palmitic), 16:1 and 18:1 (oleic) than newborn indicating that these fatty acids were being utilized by the young pig. Percentages of 18:0 and 20:4 were higher than in the newborn. There was no significant difference in fatty acid content between 7 day old or 10 day fed vs fasted. Seven day old animals had a significant lower percent of 14:0, 18:0 and 20:4 than animals at birth but 18:1 and 18:2 were significantly higher. Ten day fed pigs increased in percent 18:1 but decreased in 18:0, 18:2 and 20:4. These data support the hypothesis of differential utilization of fatty acids by the neonatal pig during fasting, which may explain some of the variation observed in studies on fat utilization.

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 the neonatal pig. 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 killed two hours post delivery and received no diet. The rate of oxidation of [U -$^{14}$C] palmitate to $CO_2$ and acid soluble products was measured in homogenates of liver, kidney, heart or leg muscle from pigs 0, 1, 7 and 21 days of age. The relative rates of oxidation of [U - $^{14}$C] myristate (14:0), [U - $^{14}$C] palmitate (16:0) and [U - $^{14}$C] 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 leg muscle tissue and was maximum at 21 days in kidney and leg muscle and seven days in liver. The rate of oxidation of palmitate in heart tended to decrease with animal age. Palmitate was oxidized at a faster rate than stearate or myristate in homogenates of liver from seven day old pigs.

The rates of oxidation of lauric (12:0), palmitic (16:0), oleic (18:1) and linoleic (18:2) acid by the one or seven day old pig were studied by Miller et al. (1971). Differences due to digestion and absorption were eliminated as labeled fatty acids were injected intramuscularly. 12:0 was oxidized significantly more rapidly than 16:0. Oxidation rates between 18:1 and 18:2 were not significantly different although a trend toward faster oxidation of 18:1 was observed. Cumulative recoveries at 480 minutes post injection were 46.7 and 19.9 percent for 12:0 and 16:0, respectively. 12:0 was oxidized significantly more rapidly than 18:1 and 18:2, respectively. There were no significant treatment effects due to age on fatty acid oxidation or cumulative $^{14}CO_2$ production observed. However, there was a trend toward faster fatty acid oxidation in the older pig.

In addition to level and type of fat, it has been suggested that particle size may influence fat utilization by the young pig. Sheffy et al. (1951) studied the effect of particle size and phospholipid on growth and fat utilization by the young pig. These studies utilized newborn or two day old pigs allowed to nurse. There were no significant differences in average daily gain observed between treatment groups where emulsification of lard was effected by the use of soy lecithin. When no phospholipids were used in an attempt to homogenize the fat, only two day old pigs survived. Particle size had no significant effect on feed utilization of two day old pigs where phospholipid was used. With no colostrum, a trend for a decrease in efficiency with an increase in particle size was observed. No consistent differences in fat digestion due to differences in particle size were observed.

In general, the ability of the neonatal pig to utilize fat as an energy source is poorly understood. Since pigs perform well on sow's milk which is high in fat, they are able to efficiently utilize at least one source of fat. There appears to be differential fatty acid utilization in the neonatal pig which may partially explain the variation seen in fat utilization. Further research is needed to determine the influence of degree of saturation and chain length of the fatty acids on pig performance. These characteristics may be altered by selection of type of fat or processing and may influence the ability of the pig to efficiently utilize fat supplemented diets. There also appears to be an increase in fatty acid oxidation with age in the pig.

## Fat Utilization by the Early Weaned Pig

### Performance of Pigs Fed Rations in Which Fat was Substituted for a Dietary Component on a Weight Basis

In a study comparing the utilization of supplemental lard, tallow, soybean oil and coconut oil added to the control diet at varying levels at the expense of an equal amount of other dietary ingredients, Eusebio et al. (1965) concluded that the young pig was unable to efficiently utilize the fats tested. Fat source did not significantly influence fat digestion. However, in one experiment, pigs fed soybean oil gained significantly less than those fed the control or coconut oil diets. In another experiment, total gain of pigs fed lard was less than for tallow, soybean oil or the control diet. Coconut oil which is a lower molecular weight, highly saturated fat was more readily digested and supported more rapid and more efficient gains than other fat sources.

In an early study conducted by Leibbrandt et al. (1967) comparing diets containing 10 percent hydrolyzed animal-vegetable fat (HAVF), lard, tallow or starch, no significant differences in gain or feed efficiency were observed. In a more recent study, Leibbrandt et al. (1975) compared

5 or 10 percent lard or hydrolyzed fat and 10 percent lard, tallow or fat substituted for corn starch on an equal percent basis. Fat addition did not significantly improve weight gains but pigs fed 5 percent fat diets gained more than those fed 10 percent fat. Feed to gain was significantly reduced for diets containing lard but unchanged for hydrolyzed fat. Pigs consumed more of the diets containing added fat suggesting an increase in palatability with fat addition.

The effect of feeding various levels of fat and protein was studied by Peo et al. (1957). The experimental diets contained all combinations of 0, 2.5, 5 and 10 percent lard with 15, 20, 25 and 30 percent protein. There was an increase in energy content in the ration with an increase in percent fat and protein. No significant fat x protein interactions were found and there were no significant differences in gains attributable to fat level for either the first two weeks or the entire four week test period. With an increase in percent fat, there was a significant linear decrease in feed efficiency for the first two weeks but this was not significant for the entire four week test period.

In a series of experiments conducted by Frobish et al. (1970) in which various sources of fat were substituted for an equal quantity of starch, weight gain for the control group was similar to that for pigs fed diets with added fat. There were no significant differences in feed efficiency among all diets but the control group required less energy per unit gain than those fed fat supplemented diets. Feed efficiency with butter was greater than with corn oil or lard but addition of fat did not significantly improve feed efficiency over the control diet containing no added fat. In one experiment comparing casein vs isolated soybean protein with lard fed at the level of 0, 5 or 10 percent in semipurified diets, there was a significant quadratic regression of weight gain on fat level which resulted from a marked improvement in gains from increasing fat level from 0 to 5 percent, whereas there was a slight decrease in gains beyond the 5 percent added fat level. Pigs fed the diet containing 5 percent added fat required 9.5 percent less energy per unit gain than did pigs fed the control diet and increasing the added fat level from 5 to 10 percent increased the energy requirement 6 percent per unit gain.

Several experiments have been conducted by Frobish et al. (1969) to study the effect of diet form and emulsifying agents on fat utilization by young pigs. This research group theorized that apparent inefficient utilization of some types of supplemental fat may be related to the physical characteristics of the fat and diet. Phospholipids (lecithin) maintain fat in an emulsified form. Their naturally occurring content in sow's milk is 1 to 2 percent. In these experiments, fat was substituted for an equivalent amount of starch in the corn-soybean meal based diet in experiment one and dextrose in experiments two and three. In the first experiment, dietary treatments were 10 percent lard or lard oil, lard oil plus lecithin or emulsifier and lard oil plus lecithin and emulsifier. Pigs fed diets with added fat gained less and in general required more feed per unit of gain than the basal group. Addition of lecithin and/or emulsifier did not improve the utilization of fat. Pigs fed the diet with added lard required less feed per unit of gain than pigs on the other diets, however, they required more energy per unit of gain than pigs on the basal diet. Dried skim milk was used as a protein base in experiments two and three to insure quantity and quality of protein was not limiting. In experiment two, the effect of diet form was studied using the basal diet with or without added fat in a liquid or dry form and an additional treatment limiting the intake of the basal dry diet to the amount consumed *ad libitum* by the dry diet plus fat in order to equalize nutrient intake. There were no significant differences due to treatment, however, pigs fed liquid diets tended to gain more and required less feed per unit of gain than those fed dry diets. The addition of fat to dry or liquid diets depressed average daily gain and increased energy required per unit of gain. Experiment three included an additional treatment in which intake of the basal liquid diet was limited to the amount consumed *ad libitum* by pigs fed liquid plus fat. Pigs fed fat supplemented diets gained less and required more energy per gain. In contrast to experiment two, feed efficiency was significantly improved by pigs fed liquid diets compared to dry. The addition of fat to a liquid or dry diet resulted in a decrease in intake and consequently a decrease in intake of protein and other nutrients. The regulation of nutrient intake other than energy to equal consumption of the diets with added fat indicated pigs fed the basal dry diet were equal to or superior to the dry diets plus fat. The restricted nutrient intake of liquid diets decreased growth and significantly increased feed to gain indicating that the level of intake may be the limiting factor in fat utilization. Equalizing nutrient intake, other than energy intake, demonstrated that protein and other nutrient intake were not limiting efficient utilization of fat. In general, in studies where fat was substituted for a dietary component on a weight rather than caloric basis, the young pig was unable to efficiently utilize fat as an energy source.

## Performance of Pigs Fed Rations in Which Fat was Substituted for a Dietary Component on a Caloric Basis

In one study conducted by Allee et al. (1971b) isocaloric diets containing 1, 4, 7 and 10 percent tallow were compared. Pigs fed the 4, 7 and 10 percent fat diets tended to gain faster and more efficiently than those consuming 1 percent fat diets. In a similar study comparing isocaloric diets containing 1 or 13 percent corn oil (Allee et al., 1971a), the pigs fed 13 percent corn oil gained faster and appeared to be more efficient than those fed 1 percent corn oil. As the result of a series of experiments utilizing isocaloric diets with varying percentages of corn oil, Allee et al. (1971a) concluded that by the use of diet formulation methods that maintained a constant ratio of each nutrient in the diet to the concentration of metabolizable energy, the young pig is capable of utilizing fat calories as efficiently as carbohydrate calories.

A series of experiments conducted by Cline et al. (1977) confirm the findings of Allee et al. (1971a). The pigs used in these experiments were raised by an Autosow and fed liquid diets. A mixture of corn and peanut oil was supplemented into the isocaloric diets in order to provide 12, 25, 43, 58 and 74 percent of the nonprotein calories as fat. Rate of gain of pigs from three to five weeks of age was not adversely affected by increasing percent fat calories in the diet. Dry matter per unit gain tended to decrease as fat percent increased. Cline et al. (1977) concluded that the young pig is capable of utilizing fat calories efficiently when the pigs receive equal amounts of all other nutrients or when the protein to calorie ratio is kept constant.

Two studies were conducted by Scherer et al. (1972; 1973b) using isocaloric diets with varying levels of lard substituted for dextrose on an isocaloric basis. As a result of these trials, this group has concluded that the early weaned pig cannot utilize lard for weight gain as efficiently as it can utilize dextrose. Dietary fat source may partially account for the discrepancies when comparing this trial to those previously cited.

The method of fat substitution into early weaned pig diets may greatly influence the ability of the pig to efficiently utilize fat as an energy source. Care must be taken when comparing the results of trials where fat is substituted for an equal quantity of a dietary component or where fat is substituted on an isocaloric basis. Generally, in trials utilizing fat substituted for a dietary component on a weight basis, the young pig is unable to efficiently utilize fat as an energy source as shown by depressed gains and poor feed efficiency when compared to low fat diets. On the other hand, when fat is substituted for a dietary component on an isocaloric basis or when the ratio of nutrients to energy is held constant, it appears that the young pig may be capable of utilizing fat calories as efficiently as carbohydrate calories.

## Factors Effecting Fat Utilization

Effect of level of fat on pig performance. Level of fat in the diet may influence the ability of the early weaned pig to efficiently utilize fat. Allee and Hines (1972) conducted a trial to study the effect of fat level and calorie:protein ratio on pig performance. The levels studied included 0, 3, 6, 9, 12 and 15 percent fat in which the calorie:protein ratio remained constant and 6, 9, 12 and 15 percent fat where the calorie: protein ratio was not adjusted with increasing levels of added fat. With a constant calorie:protein ratio, daily gains did not differ significantly due to fat level and 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 difference in rate of growth or cumulative gain was observed. The efficiency of feed utilization improved with an increase in level of fat calories in the diet.

The results of several studies indicate that as fat level in the diet increases there may be a decrease in pig performance or a maximumly desirable level of fat in the diet observed at a low level. 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. An increase in fat level did not improve feed efficiency and in general tended to decrease rate of gain. Specific gravity measurements of live pigs indicated deposition of fat increased as dietary level of fat increased. These data indicate that the young pig is relatively inefficient in utilizing lard, tallow, soybean oil and to a lesser extent coconut oil. A study conducted by Peo et al. (1957) supports these observations. Performance of young pigs was studied in a factorial experiment utilizing four levels of protein (15, 20, 25 and 30 percent) and four levels of stabilized lark (0, 2.5, 5 and 10 percent). The results of the first two weeks on test averaged across all levels of protein indicated that gains did not improve with an increase in percent fat and that significantly more feed was required per unit of gain with an increase in percent fat in the diet. Results over the entire four week test period indicated that there were no differences due to treatment for gain or efficiency. The results of a trial conducted by Frobish et al. (1970) indicate that there is a significant quadratic effect of fat level on gain. Lard was incorporated into the diets at the levels of 0, 5 and 10 percent. The quadratic effect observed was due to a marked improvement in gain from 0 to 5 percent with a slight decrease in gains beyond the 5 percent level. With an increase in fat level, a significant linear improvement in feed efficiency was also observed. The calorie:protein ratio was not maintained in the studies conducted by Eusebio et al. (1965), Peo et al. (1957) or Frobish et al. (1970) which may partially explain why pigs were not able to efficiently utilize the supplemental fat.

The effect of level of fat in the early weaned pig diet is not clearly understood. It appears that when the calorie:protein ratio is held constant with an increase in 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. There appears to be a limit to the amount of fat a young pig can efficiently utilize and certain fat sources may be more efficiently utilized than others. Since age of pig on trial varies among the experiments summarized, it is also possible that fat level is confounded with age of pig thereby making interpretation more difficult if not impossible.

Effect of age and enzyme development on fat utilization. Several studies have indicated that the ability of the young pig to utilize fat as an energy source increases with age (Eusebio et al., 1965; Hamilton and McDonald, 1969; Frobish et al., 1971; Scherer et al., 1973b). Lloyd et al. (1957) conducted a trial to specifically study the digestibility of ration nutrients by three- vs seven-week old pigs. Apparent digestibility, as determined by the chromic oxide technique, tended to increase with age for dry matter, energy, crude protein and ether extract, however, differences were only significant for calories and crude protein. The greatest numerical differences occurred in the ether extract fraction but it did not reach significance due to high variability within age group. The experimenters postulated that the increase in digestibility of fat with advancing age may be due to an increase in bile secretion, resulting in an increased absorptive capacity for fat. In order to further study fat digestibility, pigs were weaned at two weeks of age and were fed the same ration but to which 13 different fats or oils were added individually at the level of 20 percent. Apparent digestibility was determined at three and seven weeks of age. With the exception of total carbohydrates, average apparent digestibility of all fractions studied were significantly greater at seven vs three weeks. A highly significant inverse relationship was found between mean molecular weight (length of chain) of the fatty acids of the various fats and oils and their apparent digestibility by the early weaned pig.

Leibbrandt et al. (1975) conducted a trial to study the effect of level and source of fat on baby (4.6 kg) and growing (23.1 kg) pigs. Lard or hydrolyzed fat was utilized at 5 or 10 percent in the diet. The results of the trial using baby pigs indicated that weight gain was not affected by fat source but decreased with an increase in percent fat. Feed efficiency was improved with lard. Weight gain was improved with increasing levels of fat in the diet when using growing pigs. However, feed required per unit of gain also increased with an increase in fat level.

The effect of diet, weaning age, age of pig and fat source on lipogenesis in the young pig has been studied by several researchers

(Hartman et al., 1961; Allee et al., 1971a,b,c; Frosbish et al., 1971; Mersmann et al., 1973; Scherer et al., 1973a,b). Mersmann et al. (1973) studied the effect of diet and weaning age on in vitro lipogenesis in young swine. Glucose utilization by adipose tissue slices and activity of a number of enzymes concerned with fat synthesis were studied in order to evaluate chronological age, age of weaning and accessibility of creep feed upon emergence of high rates of lipogenesis. Flucose incorporation into $CO_2$ or lipids was increased in animals weaned at 21 or 35 days, while those weaned at 14 days had only marginal increases. Enzyme activities generally reacted in the same manner. Animals fed creep generally had increased glucose incorporation into lipids as well as increased enzyme activity.

The effects of diet and age on pancreatic lipase activity and fat utilization in pigs was studied by Scherer et al. (1973b). Pigs were weaned at two weeks of age and provided diets with 0, 6 or 12 percent lard substituted for dextrose on a caloric basis. There was a trend for decreased gains and an improvement in feed efficiency with an increase in percent fat. Apparent digestibility of fat increased with added fat and improved quadratically with age. Lipase activity increased with an increase in percent fat. It also increased in activity to weaning but markedly decreased with weaning, then increased after four weeks of age.

Hartman et al. (1961) studied the digestive enzyme development in the young pig by comparing pigs nursing their dams with those weaned at one week of age and then fed self-fed dry diets. The early weaned pigs grew more slowly from one to four weeks and at equal rates from four to five weeks of age and more rapidly for the remainder of the period. Tissue tributyrinase activity found in the pancreas of unweaned pigs was comparatively high at birth and increased with age. Weaning caused a marked decrease in tributyrinase activity.

The effect of fat source on pancreatic lipase activity and specificity and performance of baby pigs was studied by Frobish et al. (1971). Pigs were slaughtered at 14 and 56 days to determine lipase activity and substrate specificity with an increase in age. Tributyrin, butter, coconut oil and lard were the substrates used. The results indicated that pancreatic lipase activity was greater at 56 days than 14 days of age. Lipase activity was affected by the substrate used in the assay. Tributyrin was hydrolyzed more rapidly than other fat sources and coconut oil was hydrolyzed faster than lard. Coconut oil was hydrolyzed more rapidly than butter or lard and butter was hydrolyzed more rapidly than lard.

The ability of the young pig to utilize fat as an energy source increases with age. This is probably due to several factors and may confound the interpretation of experimental results when comparing pigs of different age groups. Pancreatic lipase and tributyrinase activities increase with age. Weaning stress exerts a depressing effect on the activities of these enzymes but this is recovered with time. Prexperimental handling, i.e., weaning immediately prior to being placed on trial, allowing for an adjustment period and availability of creep feed may influence the digestive enzymes and, therefore, the ability of the young pig to utilize fat.

Effect of fat source on fat utilization. Source of fat influences the ability of the young pig to utilize fat supplemented diets. Fatty acid chain length and degree of saturation may be major factors causing this differential utilization of fats. The effect of dietary fat source on apparent digestibility of fat and the composition of fecal lipids of the young pig was studied by Hamilton and McDonald (1969). The experimental diets contained 10 percent coconut oil, rapeseed oil, lard or tallow. None of the differences in average percent digestibility of dietary fat was related to fat source. Dietary fat source did not affect average daily gain, feed to gain or apparent digestibility of protein, dry matter or fat. Apparent digestibility of palmitic and stearic acids were lower than those of unsaturated or medium - chain saturated fatty acids.

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. Twenty different fats were added individually to a low-fat basal ration at the level of 20 percent and chromic oxide was used to estimate fat digestibility. A highly inverse relationship was found to exist between mean molecular weight (chain length) of the fatty acids of various fats and oils and their apparent digestibility. Approximately 30 percent 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 utilization of various dietary fats by early weaned pigs 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. Chromic oxide was used to determine fat and fatty acid digestibility. There were no significant differences in gain due to fat source, however, pigs fed corn oil tended to gain more rapidly. The digestibility of the total lipid fraction of the diet containing corn oil was significantly greater than that of any of the other three diets. The mean absorbabilities of oleic (18:1) and linoleic acid (18:2) were

98 percent regardless of the type of other fatty acids present in the diet. There were no significant differences in absorbability of 18:1, 18:2 or 16:0 although absorbability of palmitate (16:0) was less (91 percent). There was a significant decrease in the absorbability of stearic acid (18:0) as compared to the other three. Stearate was more poorly absorbed when corn oil was the fat source than when either tallow or lard was fed. Absorbabilities were 28.5, 81.4 and 78.4 percent with corn oil, tallow and lard, respectively. Apparently the absorbability of stearic acid is depressed when fed in combination with high amounts of unsaturated fatty acids.

The composition of lipids in intestinal digesta of young pigs receiving diets containing tallow and tallow free fatty acids was studied (Swiss et al., 1976) by aspirating jejunal digesta samples at 1.5, 2.5, 3.5 and 4.5 hours post feeding. Ten percent fat was substituted into the basal ration for 5 percent corn starch and 5 percent cerelose. The digesta samples were separated into aqueous (micellular) and oil phases. Free fatty acids were the predominant component of the aqueous and oil phase but appreciable concentrations of triglycerides and monoglycerides were present in the oil phase. Therefore, the lower digestibility of completely hydrolyzed beef tallow when compared to beef tallow was not due to an absence of monoglycerides in the intestinal lumen. The proportion of stearic acid in the jejunal digesta was greater than in the dietary lipid and there was a lower proportion of palmitic and oleic acid in the jejunal digesta than in the diet. The ratio of oleic to palmitic acid in the aqueous phase was less than in the lipid phase suggesting preferential uptake of oleic acid from the micelle by the intestinal mucosa.

Swiss and Bayley (1976) studied the influence of degree of hydrolysis of beef tallow on its absorption by young pigs. Beef tallow was hydrolyzed to provide 3, 10, 20, 46 and 100 percent free fatty acids and was fed at the level of 10 percent in simipurified diets. Tridodecyl glycerol ether was used to estimate fat absorption. The corrected absorbabilities of 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 acid were well absorbed in intact and partially hydrolyzed tallow (82 to 84 and 63 to 77 percent, respectively) but absorption was impaired in completely hydrolyzed tallow (62 and 38 percent, respectively).

The amounts of fatty acids in the digestive tract was studied by Carlson and Bayley (1972) using a fat soluble indicator of absorption, tridodecyl glycerol ether (DGE). The author 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 intestines, addition of endogenous fat to digesta and modifications of unabsorbed fat residues in the large intestines. Ten percent beef tallow replaced 10 percent glucose in the experimental diets. One diet was fed with DGE and chromic oxide and one with chromic oxide only as well as control plus chromic oxide. Substitution of beef tallow for glucose resulted in a significant decrease in feed intake and weight gain between 13 and 23 days of age. Apparent digestibilities of beef tallow diets were significantly lower than for the low fat diet. DGE did not influence digestibility, therefore, it was accepted as an adequate marker. The calculations based on the ratio of fatty acids to chromic oxide suggests that there is a net secretion of fatty acids into the stomach, but earlier observations suggested that this was due to chromic oxide separating from the fatty acids in the stomach and moving into the small intestines ahead of the fatty acids, therefore, meaningful absorbabilities of the fatty acids from regions of the digestive tract distil to the stomach could not be calculated with chromic oxide as an absorption indicator. In contrast, DGE showed no change in amount of fatty acid equivalent to one kilogram of 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 intestines.

The portions of saturated acids, palmitic and stearic, were greater in the digesta taken from successively lower regions of the digestive tract. Modifications of the fatty acids in the digestive tract which occurred after digesta had passed beyond the region where fatty acid absorption is believed to be completed, casts doubt on the validity of using digestibilities of individual fatty acids as a measure of the extent to which they can be absorbed from different fats by the animal. Changes in fatty acid composition of fat in the large intestines could be due to the addition of saturated fatty acids in the lower region of the digestive tract or hydrogenation of unsaturated fatty acids shown to be associated with microflora of the large intestines. In this study, there was a net disappearance of unsaturated fatty acids from the small intestines. The increase in stearic acid (18:0) was almost equal to the decrease in amounts of 18 carbon fatty acids. The determination of either 'apparent' or 'corrected' digestibilities of individual fatty acids in natural foods must be considered of limited usefulness in critical experiments designed to study the factors limiting fatty acid utilization by comparing food intake and fecal output. Objectives of such studies would be better served by direct examination of small intestinal digesta.

The fatty acid composition of a dietary fat may influence the ability of the early weaned pig to efficiently utilize the fat. 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. With an increase in the degree of hydrolysis in free fatty acids there tends to be a decrease in the digestibility of the fat. Individual fatty acids appear to be utilized to a different extent by the young pig and combinations of fatty acids may influence the utilization of a given fatty acid. The proportion of stearic (18:0) and palmitic acid (16:0) tends to increase in digesta taken from progressively lower portions of the digestive tract. Apparent digestibilities of stearic and palmitic acids tend to be lower than unsaturated medium chain fatty acids. Oleic (18:1) and linoleic acid (18:2) which are long chain, unsaturated fatty acids are very readily absorbed and palmitic acid (16:0) is highly absorbed but to a lesser degree. The absorbability of stearic acid (18:0) is greatly influenced by the fatty acid composition of the dietary fat. The apparent digestibility of stearic acid is significantly lower when fed in a highly unsaturated diet. Modifications of fatty acids in the digestive tract after the region of absorption casts doubt on the validity of using apparent digestibility of fatty acids as a measure of utilization by the young pig. Analysis of digesta would be a more valid estimate of the ability of the pig to utilize different fatty acids.

CHAPTER III

# EFFECT OF DIETARY FAT SOURCE ON THE PERFORMANCE OF COLOSTRUM DEPRIVED NEONATAL PIGS

## Summary

The effect of dietary fat source in liquid, semipurified diets was studied in a trial utilizing 22 cesarean section derived Yorkshire pigs. The four treatment groups included diets containing 32 percent fat on a dry matter basis. Fat sources used were butterfat, corn oil, coconut oil and lard. Pigs were individually housed in sterile isolators from day 0 to 14 and on day 14, pigs were transferred to elevated metal pens in the nursery. Pigs were fed the warmed diet five times daily at 0600, 1000, 1400, 1800 and 2200 hours. Polyethylene glycol (PEG) was fed at the level of .5 mg/ml of diet starting at 1400 hours on day 14 through day 18 in order to estimate apparent digestibility of total lipids and fatty acids. PEG was withdrawn from the diet on day 19 and 20 in order to estimate digesta turnover rate. Feed consumption was recorded and pig weights were taken on days 0, 7, 14 and 20. There were no significant differences in feed efficiency (liters/kg gain) for 0 to 14 days ($P>.32$) or 14 to 20 days ($P>.27$). However, for the entire 20 day treatment period, feed efficiency values for coconut oil were lower than for corn oil ($P<.01$) and lard ($P<.06$). Feed efficiency values over the entire treatment period were 3.81, 4.30, 3.53 and 4.16 liters per kg of gain for butterfat, corn oil, coconut oil and lard, respectively. There were no significant

treatment differences in average daily gain (ADG) for 0 to 7 ($P>.96$) or 7 to 14 days ($P>.21$). However, ADG from 14 to 20 and from 0 to 20 days was significantly affected by fat source. Pigs fed coconut oil had a higher ADG than pigs fed corn oil ($P<.03$) and lard ($P<.01$) during both time periods. ADG values for the entire treatment period were .151, .137, .163 and .138 kg/day for butterfat, corn oil, coconut oil and lard, respectively. A stepwise regression procedure used to evaluate the effects of unsaturation and chain length of fatty acids on pig performance indicated that the best model contains both short and long chain fatty acids as linear and quadratic effects ($P<.01$) on gain and efficiency of gain. The model accounted for 44 percent of the variation in ADG and feed efficiency. However, only specific combinations of fatty acids were included and that could have a large effect on the results of such an analysis.

## Introduction

Sow's milk contains approximately 30 percent fat on a dry matter basis (Perrin, 1955; deMan and Bowland, 1963). Pigs perform well on their mother's milk and this would suggest that young pigs are capable of utilizing a high fat diet. Research conducted by Wolfe et al. (1977) has suggested that the neonatal pig is capable of efficiently utilizing a high fat diet (32 percent fat on a dry matter basis) when butterfat is used as the fat source. Studies conducted by Braude and Newport (1973) suggest that the ability of the neonatal pig to efficiently utilize dietary fat is dependent upon fat source. The fat content of the pig at birth is approximately 1.5 percent and increases by two weeks of age to 15 percent (Manners and McCrea, 1962). It has been hypothesized (Friend, 1974) that since the neonatal pig has such a propensity to store fat, it will have a parallel ability to metabolize it.

This study was conducted to determine the effects of source of dietary fat on the performance of colostrum deprived neonatal pigs and to estimate apparent digestibility of total lipid and individual fatty acids and digesta turnover rate using the water soluble marker, polyethylene glycol.

## Materials and Methods

The effect of dietary fat source in liquid, semipurified diets was studied in a trial utilizing 22 colustrum deprived Yorkshire pigs that were derived by cesarean section. The cesarean sections were performed on approximately day 113 of gestation by a procedure similar to that described by Coalson et al. (1973). The four treatment groups included diets containing 32 percent fat on a dry matter basis. Fat sources used were butterfat, corn oil, coconut oil and lard (Table I). Sources of fat were selected to vary both chain length and degree of unsaturation of fatty acids (Table II). Pigs derived from two litters consisting of 11 and 17 pigs were assigned at random within litter and sex to treatment and to isolator. Least squares procedures were used to analyze average daily gain and feed efficiency. The following linear model was considered $Y_{ij} = \mu + B_i + T_j + BT_{ij} + e$ where $Y_{ij}$ is the observation, $\mu$ is the general mean, $B_i$ is the effect of the $i^{th}$ block (litter), $T_j$ is the effect of the $j^{th}$ treatment, $BT_{ij}$ is the interaction of the $i^{th}$ block and the $j^{th}$ treatment and e is the random error. A stepwise regression procedure from SAS 79 was used to evaluate the effects of unsaturated fatty acids and short and long chain fatty acids on gain and feed efficiency. Means reported are Least Square Means and the difference between means was determined by a t-test.

TABLE I

COMPOSITION OF LIQUID DIETS[a]

| Composition of Liquid Diets[b] | |
|---|---|
| Water | 778.92 |
| Fat | 86.49 |
| Nutritek - 900 (Sweet dairy whey) | 60.00 |
| Calcium caseinate (1.3% calcium) | 80.00 |
| Citric acid (monohydrate) | 1.30 |
| Choline chloride | 0.20 |
| Lecithin | 0.27 |
| Vitamin premix[c] | 2.00 |
| Mineral premix[d] | 12.50 |
| Calcium chloride | 0.80 |

[a]Diets formulated to meet approximately 1.3 times NRC requirements for 1 to 5 kg pig.

[b]All values expressed as g/liter.

[c]Vitamin premix supplied 0.9375 g Vitamin A (500,000 IU/g), 0.0938 g Vitamin $D_2$ (500,000 IU/g), 0.0277 g thiamine hydrochloride, 0.6392 g riboflavin, 4.6884 g niacin, 3.0118 g calcium pantothenate (92% Pantothenic acid), 0.0320 g Vitamin $B_6$, 4.6884 g Vitamin $B_{12}$ (0.1% $B_{12}$ in mannitol), 2.2800 g PABA, 7.5850 g ascorbic acid, 20.2900 g inositol, 0.1279 g folic acid (Folacin), 0.0210 g biotin, 9.3800 g Vitamin E (250 IU/g), 0.4262 g Vitamin K and 945.7711 g dextrose.

[d]Mineral premix supplied 200.0000 g $NaHCO_3$, 520.2026 g $KH_2PO_4$, 90.0000 g $MgSO_4.7H_2O$, 0.2726 g $MnSO_4.H_2O$, 9.7440 g $ZnSO_4.7H_2O$, 0.5222 g $CuSO_4.5H_2O$, 8.4390 g $FeSO_4$, 0.0041 g KI, 170.8000 g $CaCl_2$ and 0.0155 g $Na_2SeO_4.12H_2O$.

TABLE II

FATTY ACID COMPOSITION OF FATS AND OILS

| | Percent fatty acids[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Fat or oil | 10[b]:0[c] | 12:0 | 14:0 | 16:0 | 16:1 | 18:0 | 18:1 | 18:2 |
| Butterfat | 1.4 | 3.4 | 10.3 | 31.6 | 7.1 | 14.0 | 27.8 | 4.6 |
| Corn oil | | 0.8 | | 10.9 | | 2.3 | 25.6 | 60.5 |
| Coconut oil | 4.2 | 32.7 | 26.1 | 16.3 | 1.6 | 3.7 | 12.3 | 1.5 |
| Lard | | 1.3 | 1.5 | 21.5 | 4.0 | 11.5 | 46.1 | 14.1 |

[a]Fatty acid methyl esters were separated on a diethylene glycol succinate column in a Perkin-Elmer 990 gas-liquid chromatographic column instrument equipped with a hydrogen flame detector operated at 190°C column and 250°C injection port and detector temperature with a nitrogen flow rate of 31 ml/minute.

[b]Number of carbon atoms in fatty acid.

[c]Number of double bonds in fatty acid.

Pigs were individually housed in sterile isolators from day zero to 14. The temperature was maintained at approximately 35$^{o}$C and warmed air that passed through a micron filter flowed continuously through the isolators. Fluorescent lights remained on from 0600 to 2200 hours daily and ultra violet lights remained on at all times. The initial feeding, at approximately two hours post delivery, was 35 ml. The amount of liquid diet fed was increased 5 ml at 0600 hours and 5 ml more at 1400 hours each day as long as the pigs appeared healthy and had cleaned up the previous meal. Pigs were fed the warmed diet five times daily at 0600, 1000, 1400, 1800 and 2200 hours. Feed consumption was recorded and pig weights were taken at 0, 7, 14 and 20 days of age. Pigs were transferred to the nursery room on day 14 where they were randomly allotted to pens and individually housed in elevated, open topped metal pens until the completion of the trial on day 20. The temperature was maintained at approximately 26$^{o}$C. Polyethylene glycol (PEG) was fed at the level of .5 mg/ml of diet starting at 1400 hours on day 14 through day 18 and composite fecal samples were collected on days 16, 17 and 18 in order to estimate apparent digestibility of total lipid and individual fatty acid. PEG was withdrawn from the diet on days 19 and 20 and individual fecal samples were collected at two hour intervals starting at 0600 hours on day 19 and continuing through 1600 hours on day 20 in order to estimate digesta turnover rate.

Protein, moisture and ether extract were determined by Official Methods of AOAC (1965). Methyl esters of the fatty acids of the dietary fats were prepared by heating for three to four hours the fatty acid sample plus 4.0 ml sodium dried benzene, 0.4 ml DMP 2, 2-Dimethoxypropane and 0.5 ml MeOH-HCl methonolic HCl. This was then dried under nitrogen conditions and then diluted with sodium dried benzene. All fatty acid methyl esters were separated on a diethylene glycol succinate (DEGS) column in a gas-liquid chromatographic column instrument[1] operated at 190°C column and 250°C injection port and detector temperature with a nitrogen flow rate of 30 ml/minute (Mason and Waller, 1964).

## Preparation of Diets

The liquid diets (Table I) not containing the marker were prepared several days prior to surgery and frozen. The diets containing PEG were prepared just prior to day 14. The liquid diets were prepared by mixing the dry ingredients into very warm tap water in a 10 gallon milk can. The mineral premix was added very slowly to prevent it from effervescing since it contained anhydrous ingredients. Nutritek 900 and calcium caseinate were the last dry ingredients added to prevent lumping. The melted fat was added last. PEG was dissolved in warm water before adding it to the liquid diet. The diets were homogenized and pasteurized at approximately 74°C and stored in milk cartons.

## Preparation of Pig Facilities

The anteroom and isolator room were prepared as close to the day of surgery as possible. The rooms and equipment were throughly cleaned with detergent solution and all materials needed for the trial were placed in the anteroom. The walls and floors were sprayed just prior to fumigation with a Roccal-Nolvasan[2] solution and the rooms were fumigated overnight with formalogen.

After the rooms were disinfected and fumigated, enough feeding

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[1]Perkin-Elmer 990 with hydrogen flame detector.
[2]Roccal - Winthrop Laboratories, Nolvasan - Fort Dodge Laboratories.

equipment for two feedings was prepared and then placed in the anteroom the day before surgery. The equipment included 1000 ml beakers, blunted needles and holder, 100cc syringes, spare nipples for the feeding troughs plus umbilical clamps and thermometers. A beaker was placed upside down in a paper bag and then the top of the bag was rolled several times and sealed with autoclave tape. The needles were placed in the needle holder and covered with an autoclave bag. Nipples and umbilical clamps were also placed in autoclave bags. The 100cc syringes were placed in their plastic containers and a strip of autoclave tape was placed across the seal. All equipment plus two asbestos gloves were placed in a carrying tray and were autoclaved at 100°C for at least 30 minutes. An extra tray to store used equipment was also sterilized.

The transfer boxes and isolators were constructed prior to surgery and were autoclaved and placed in the isolator room not longer than 24 hours prior to surgery. They were constructed from cardboard boxes with the finished dimensions of 61 cm long by 30 cm wide by 30 cm deep. Transfer boxes were used to transport pigs from the recovery room to the isolator room.

## Feeding Procedure

Pigs were fed each day at 0600, 1000, 1400, 1800 and 2200 hours. Precautions were taken to minimize the chance of contaminating the pigs. All personnel had no outside contact with pigs. Upon entering the anteroom, the air was immediately sprayed with Nolvasan[3] solution. Rubber boots were placed over the feeder's shoes and were then dipped into a Roccal-Nolvasan foot bath. A mask was placed over the nose and mouth as

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[3]Fort Dodge Laboratories.

soon as possible after entering the room and was worn at all times. Hands and arms were washed and a lab coat and rubber gloves were worn. The liquid diets were then placed in the water bath to warm. The push cart was cleaned with Roccal-Nolvasan solution and the warmed liquid diets were placed on it along with the feeding equipment, disinfectant spray bottle and flash light. The cart was pushed into the isolator room and the air was sprayed with disinfectant. The pigs were checked before feeding for signs of sickness and to see if they cleaned up the previous meal. The liquid diet was agitated to insure proper mixing and poured into a beaker. A separate beaker was used for each treatment. The diet was measured with a 100cc syringe equipped with a blunted needle and a clean needle was used for each pig. Sick pigs were always fed last. To feed a pig, the nipple was removed from the front of the trough and the diet was injected through the opening. Feed consumption and pertinent observations were recorded after each feeding. After the 2200 hours feeding each day, the floor was scrubbed with disinfectant. Used feeding equipment was washed and prepared for autoclaving and since there was adequate equipment for two feedings, it was necessary to autoclave the equipment only every other feeding.

## Results

Overall survival rate was 84.6 percent and six pigs per treatment completed the trial with the exception of the lard treatment which consisted of four pigs. The effect of dietary fat source on the performance of colostrum deprived neonatal pigs is shown in Table III. For the entire 20 day trial, feed efficiency (liters of diet/kg gain) of pigs fed coconut oil was lower than for those fed corn oil ($P<.01$) and lard ($P<.06$).

TABLE III

EFFECT OF FAT SOURCE ON FEED EFFICIENCY AND RATE OF GAIN

| Variables | Treatment | | | |
|---|---|---|---|---|
| Fat source | Butterfat | Corn oil | Coconut oil | Lard |
| Number of pigs | 6 | 6 | 6 | 4 |
| Feed intake (liters) | | | | |
| Litter one | | | | |
| Day 0-20 | 11.63 | 11.63 | 11.63 | 11.63 |
| Day 0-14 | 6.515 | 6.515 | 6.515 | 6.515 |
| Day 14-20 | 5.12 | 5.12 | 5.12 | 5.12 |
| Litter two | | | | |
| Day 0-20 | 11.34 | 11.34 | 11.34 | 11.34 |
| Day 0-14 | 6.53 | 6.53 | 6.53 | 6.53 |
| Day 14-20 | 4.81 | 4.81 | 4.81 | 4.81 |
| Feed efficiency (liters/kg) | | | | |
| Day 0-20 | $3.81 \pm .19^{a,b}$ | $4.30 \pm .19^{a}$ | $3.53 \pm .19^{b}$ | $4.16 \pm .24^{a,b}$ |
| Day 0-14 | $3.78 \pm .19$ | $4.17 \pm .19$ | $3.68 \pm .19$ | $3.97 \pm .23$ |
| Day 14-20 | $3.91 \pm .50$ | $4.76 \pm .50$ | $3.46 \pm .50$ | $4.66 \pm .61$ |
| ADG (kg/day) | | | | |
| Day 0-20 | $0.15 \pm .01^{a,b,c}$ | $0.14 \pm .01^{a,c}$ | $0.16 \pm .01^{b}$ | $0.14 \pm .01^{a,c}$ |
| Day 0-14 | $0.12 \pm .01$ | $0.11 \pm .01$ | $0.13 \pm .01$ | $0.12 \pm .01$ |
| Day 14-20 | $0.21 \pm .01^{a,b,c}$ | $0.19 \pm .01^{a,c}$ | $0.24 \pm .01^{b}$ | $0.18 \pm .02^{a,c}$ |
| Day 0-7 | $0.07 \pm .01$ | $0.07 \pm .01$ | $0.07 \pm .01$ | $0.07 \pm .01$ |
| Day 7-14 | $0.18 \pm .01$ | $0.16 \pm .01$ | $0.18 \pm .01$ | $0.17 \pm .01$ |

[a,b,c]Means in the same row with different superscripts differ significantly ($P < .05$).

However, there were no significant differences in feed efficiency for 0 to 14 days ($P>.32$) or 14 to 20 days ($P>.27$). Feed efficiency values over the entire treatment period were 3.81, 4.30, 3.53 and 4.16 liters/kg for butterfat, corn oil, coconut oil and lard, respectively. Average daily gain (ADG) from 14 to 20 and 0 to 20 days was significantly affected by fat source. There were no significant treatment differences in ADG for 0 to 7 ($P>.96$) or 7 to 14 days (P .21). Pigs fed coconut oil had a higher ADG than pigs fed corn oil ($P<.03$) and lard ($P<.01$) during both time periods. ADG values for the entire treatment period were .151, .137, .163 and .138 kg/day for butterfat, corn oil, coconut oil and lard, respectively.

It has been suggested that differential utilization of dietary fat may be partially due to fatty acid composition. The fats used in this study were chosen to vary both chain length and degree of unsaturation of fatty acids. Generally, pigs fed coconut oil which is a short chain, highly saturated fat performed better than pigs fed the other diets even though they were not significantly different than those fed butterfat. Butterfat is intermediate in both chain length and degree of unsaturation and was used primarily as a control in this study. Pigs fed corn oil which contains predominately long chain, unsaturated fatty acids tended to perform better than those fed lard which contains predominately long chain fatty acids but is more saturated than corn oil.

It was not possible to obtain adequate fecal samples on the majority of the pigs to estimate apparent digestibility of total lipids and each fatty acid or digesta turnover rate. Several samples were lost due to scouring which might have been partially caused by the large particle size of polyethylene glycol (MW 20,000). Many samples were not large enough to analyze probably due to the high digestibility of the liquid diets, lack of bulk and young age of the pigs. However, a stepwise regression procedure from SAS 79 was used to evaluate the effects of unsaturated fatty acids and short and long chain fatty acids on gain and feed efficiency. The model included fatty acids with a chain length of 16 or less as short chain (cupric-10:0, lauric-12:0, myristic-14:0 and palmitic-16:0 acids). Stearic acid (18:0) was the single long chain fatty acid. Palmitoleic (16:1), oleic (18:1) and linoleic (18:2) acids were the predominant dietary unsaturated fatty acids and were included in the model as unsaturated fatty acids. Cupric (10:0), lauric (12:0), myristic (14:0), palmitic (16:0) and stearic (18:0) acids were the predominant dietary saturated fatty acids in the fat sources used in the experiment (Table II) and were included in the model as the saturated fatty acids.

The best model contained both short and long chain fatty acids as linear and quadratic effects ($P<.01$) on gain and efficiency of gain. The model accounted for 44 percent of the variation in ADG and 44 percent of the variation in feed efficiency. Since only a small number of various combinations of fatty acids were used, the interpretation of the results beyond the combinations used in the trial is unadvisable.

## Discussion

Very little research has been conducted to study the utilization of fat by the neonatal pig. However, data suggests (Wolfe et al., 1977) that the neonatal pig can utilize liquid diets high (32 percent on a dry matter basis) in butterfat and that energy from butterfat appears to be used as efficiently for growth as energy from glucose for growth purposes.

Data fail to agree (Catron et al., 1953; Schendel et al., 1953) if the neonatal pig is capable of efficiently utilizing supplemental lard. The results of these trials indicate that the ability of the neonatal pig to utilize dietary fat may be influenced by the source of the fat.

In a trial conducted by Braude and Newport (1973) to study the effects of different sources of dietary fat, the performance of the pigs and the apparent digestibility of fat indicated that soybean oil was equal to butterfat and that butterfat was slightly superior to coconut oil and markedly superior to beef tallow. An additional trial conducted by Braude and Newport (1973) utilizing diets supplemented with beef tallow or soybean oil support these findings. The results of these studies and the current study indicate that source of fat does influence the ability of the neonatal pig to utilize fat. The differential performance of pigs may be partially due to the fatty acid composition of the fat. Work conducted by Seerley and Poole (1974) has indicated that there is differential utilization of fatty acids by the neonatal pig during fasting which may explain some of the variation observed in studies on fat utilization. A study conducted by Wolfe et al. (1978) indicated that plamitate was oxidized at a faster rate than stearate or myristate in homogenates of liver from 7 day old pigs. In addition, a trial conducted by Miller et al. (1971) using fatty acids that were injected intramuscularly to eliminate differences in digestion and absorbtion showed that lauric acid was oxidized more rapidly than palmitic acid and oleic acid tended to be oxidized more rapidly than linoleic acid. Lauric acid was oxidized at a much faster rate than both oleic and linoleic acid. This may suggest that short chain fatty acids are oxidized more rapidly than long chain fatty acids and saturated fatty acids are oxidized at a faster rate than unsaturated fatty acids which generally supports the findings of this study. More research is needed before the utilization of dietary fat may be predicted from its fatty acid composition.

CHAPTER IV

# EFFECT OF DIETARY FAT LEVEL ON THE PERFORMANCE OF EARLY WEANED PIGS

## Summary

Effect of fat supplementation in starter pig diets on the performance of early weaned pigs was studied utilizing 68 Yorkshire boars. The four treatment groups included fortified corn-soybean meal diets containing 0, 4, 8 and 12 percent Choice White Grease. Levels of corn and soybean meal were altered to maintain a constant ratio of nutrients to energy. Pigs were individually penned and feed and water were offered ad libitum. Mean starting age on trial was 27 days and pigs were on trial for 35 days. Pigs were weighed at the start of the trial and weekly thereafter. Feed consumption was recorded for the entire period and weekly for blocks five and six only. There were no treatment differences for average daily gain (ADG, $P>.17$) or feed efficiency ($P>.18$) for the five week period. Average daily gain for the pigs fed the 0, 4, 8 and 12 percent fat diets was $.40 \pm .02$, $.39 \pm .02$, $.40 \pm .02$ and $.35 \pm .02$ kg/day, respectively. However, in the analysis of blocks five and six which included week in the model, there was a significant linear decrease in ADG with an increase in percent fat in the ration. Feed efficiency for the pigs fed the 0, 4, 8 and 12 percent fat diets was $2.03 \pm .07$, $1.82 \pm .07$, $1.92 \pm .07$ and $1.89 \pm .07$ kg feed/kg gain, respectively. When feed efficiency was analyzed for blocks five and six including week in the model, there remained

no significant (P>.63) treatment effect. Energetic efficiency analyzed over the five week feeding period appeared to be affected (P>.10) by level of dietary fat. Energetic efficiency was 6926, 6497, 7180 and 7405 Kcal/kg gain for the 0, 4, 8 and 12 percent fat diets, respectively. However, when energetic efficiency was analyzed for blocks five and six including week in the model, no significant (P>.64) treatment effects were found.

## Introduction

When pigs are weaned they undergo a weaning stress period that is characterized by decreased gains or weight loss and increased death rate (Okai et al., 1976). This is especially apparent in early weaned pigs (Mersmann et al., 1973; Okai et al., 1976). Weaning stress can be attributed to a drastic change in diet as well as environment. It has been suggested that feeding diets supplemented with a very high quality fat could reduce weaning problems and result in improved feed conversion since fat is a major source of energy in sows' milk and would represent less of a dietary change for early weaned pigs.

Several studies have been conducted to evaluate the performance of early weaned pigs fed fat supplemented diets (Peo et al., 1957; Eusebio et al., 1965; Leibbrandt et al., 1967; Frobish et al., 1969; Frobish et al., 1970; Allee et al., 1971a,b,c; Scherer et al., 1972, 1973a,b; Cline et al., 1977). However, data to date have failed to document whether the young pig is capable of utilizing fat calories as efficiently as carbohydrate calories. This study was conducted to determine the effect of dietary fat level of a very high quality fat (Choice White Grease) on the performance of early weaned pigs and to determine if Choice White Grease should be added to early weaned pig diets.

## Materials and Methods

A feeding trial was conducted with a total of 68 Yorkshire boar pigs to evaluate the effects of fat supplementation in early weaned pig diets. The four treatments included fortified corn-soybean meal diets (Table IV) containing 0, 4, 8 and 12 percent Choice White Grease (Table V). The levels of corn and soybean meal were altered to maintain a constant ratio of lysine to energy and vitamins and minerals to energy. Energy content of the diet increased with increasing levels of added fat. Pigs were assigned at random within block to treatment and to pen. Each of the six blocks initially consisted of 12 pigs with three pigs per treatment. Littermates were spread across treatments as much as possible to minimize litter effects. Data for blocks one through six were analyzed as a randomized block design using the GLM procedure of SAS 79. Means reported are least square means and differences between means were determined by a t-test. Since feed consumption was recorded on a weekly basis for blocks five and six only, data for this time period were analyzed in a randomized block design with week included in the model in addition to block, treatment and the corresponding interactions. Block five consisted of 10 pigs, one and four consisted of 11 pigs and two, three and six consisted of 12 pigs.

Pigs were individually housed in an environmentally controlled room in elevated metal pens measuring .61 by 1.10 meters. The room temperature was maintained at 24 to 27$^{o}$C. Lights remained on from 7:30 am until 4:30 pm daily. Feed and water were offered ad libitum. The average starting age on trial was 27 days and pigs were on trial five weeks. Pig weights

TABLE IV

COMPOSITION OF STARTER DIETS

| Ingredients | Percent composition (as fed basis) | | | |
|---|---|---|---|---|
| | Diet number | | | |
| | 1 | 2 | 3 | 4 |
| Corn | 68.03 | 61.60 | 55.17 | 48.74 |
| Soybean meal | 28.57 | 30.83 | 33.09 | 35.35 |
| Fat (Choice White Grease) | 0.00 | 4.00 | 8.00 | 12.00 |
| Dicalcium phosphate | 1.10 | 1.155 | 1.21 | 1.265 |
| Calcium carbonate | 1.20 | 1.26 | 1.32 | 1.38 |
| Vitamin-trace mineral premix[a] | 0.75 | 0.79 | 0.825 | 0.86 |
| Salt | 0.30 | 0.315 | 0.33 | 0.345 |
| Aureomycin (CTC 10) | 0.05 | 0.05 | 0.055 | 0.06 |
| Calculated analysis | | | | |
| Crude protein (N x 6.25) | 19.14 | 19.60 | 20.07 | 20.53 |
| Calcium | 0.81 | 0.85 | 0.89 | 0.98 |
| Phosphorus | 00.61 | 0.61 | 0.62 | 0.62 |
| Lysine | 1.00 | 1.05 | 1.10 | 1.15 |
| Methionine | 0.23 | 0.24 | 0.25 | 0.26 |
| Cystine | 0.25 | 0.26 | 0.27 | 0.28 |
| Digestible energy (Kcal/kg) | 3410 | 3578 | 3747 | 3915 |
| Actual analysis | | | | |
| Crude protein (N x 6.25) | 18.45 | 19.03 | 19.42 | 19.58 |
| Ether Extract | 2.50 | 6.76 | 9.78 | 13.29 |

[a]Vitamin-trace mineral premix supplied 181,437 IU Vitamin A; 13,608 IU Vitamin D; 181 mg riboflavin; 907 mg pantothenic acid; 1,361 mg niacin; 36,287 mg choline; .68 mg Vitamin $B_{12}$; 454 IU Vitamin E; 91 mg menadione sodium bisulfite; 9.1 mg iodine; 4.1 g iron; .9 g manganese; .45 g copper; 4.1 g zinc; and 4.5 mg selenium per kg of premix.

TABLE V

FATTY ACID COMPOSITION OF CHOICE WHITE GREASE[a]

| Fat | Percent fatty acids[b] | | | | | | |
|---|---|---|---|---|---|---|---|
| | 12[c]:0[d] | 14:0 | 16:0 | 16:1 | 18:0 | 18:1 | 18:2 |
| Choice White Grease | 1.0 | 1.4 | 23.8 | 5.0 | 12.0 | 47.9 | 9.0 |

[a]Stabilized with .005% BHT, minimum titer 37°, free fatty acid maximum 4 percent, color 11-B-13 maximum, MIU (moisture, insoluble impurities, unsaponifiable) 1 percent maximum.

[b]Fatty acid methyl esters were separated on a diethylene glycol succinate column in a Perkin-Elmer 990 gas-liquid chromatographic column instrument equipped with a hydrogen flame detector operated at 190°C column and 250°C injection port and detector temperature with a nitrogen flow rate of 30 ml per minute.

[c]Number of carbon atoms in fatty acid.

[d]Number of double bonds in fatty acid.

were taken at the start of the trial and weekly thereafter. Feed consumption was recorded for the entire five week period. Feed consumption on a weekly basis was recorded for blocks five and six.

## Results and Discussion

Effect of dietary fat level on ADG is shown in Table VI. When analyzing blocks one through six over the entire five week experimental period, level of Choice White Grease had no significant effect on total ADG ($P>.17$). ADG was .40 $\pm$ .02, .39 $\pm$ .02, .40 $\pm$ .02 and .35 $\pm$ .02 kg/day for pigs fed 0, 4, 8 and 12 percent fat diets, respectively. However, in the analysis of blocks five and six which included week in the model (Table VII), there was a significant difference in ADG due to treatment and for a block by week interaction. The treatment effect did show a significant linear response with ADG decreasing as percent Choice White Grease increased in the ration. ADG was .40 $\pm$ .02, .37 $\pm$ .02, .40 $\pm$ .02 and .33 $\pm$ .02 kg/day for the 0, 4, 8 and 12 percent fat diets, respectively.

Feed efficiency (Figure 1; Table VIII) over the five week feeding period was apparently not affected ($P>.18$) by level of dietary fat. Feed efficiency was 2.03 $\pm$ .07, 1.82 $\pm$ .07, 1.92 $\pm$ .07 and 1.89 $\pm$ .07 kg feed/kg gain for the 0, 4, 8 and 12 percent fat diets, respectively. When feed efficiency was analyzed for blocks five and six including week in the model, there was still no significant ($P>.63$) treatment effect, however, there was a significant ($P<.0001$) block by week interaction.

Energetic efficiency (Table VIII) analyzed over the five week feeding period appeared to be affected ($P>.10$) by level of dietary fat. Pigs apparently utilized the 4 percent fat diet most efficiently and the higher fat diets least efficiently, suggesting a maximally desirable level of

TABLE VI

EFFECT OF FAT LEVEL ON RATE OF GAIN[a]

| Variables | Treatment 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| % Choice White Grease | 0 | 4 | 8 | 12 |
| Number of pigs | 18 | 17 | 17 | 16 |
| Total ADG, kg/day | .40 ± .02 | .39 ± .02 | .40 ± .02 | .35 ± .02 |
| Wk 1 ADG | .09 ± .02[b] | .09 ± .03[b] | .09 ± .03[b] | -.01 ± .03[c] |
| Wk 2 ADG | .29 ± .02 | .27 ± .02 | .26 ± .02 | .23 ± .02 |
| Wk 3 ADG | .46 ± .03 | .44 ± .03 | .45 ± .03 | .39 ± .03 |
| Wk 4 ADG | .54 ± .02 | .53 ± .02 | .52 ± .02 | .52 ± .03 |
| Wk 5 ADG | .63 ± .03 | .63 ± .03 | .68 ± .03 | .62 ± .03 |

[a]Week is not included in the model for analysis of data from blocks one through six.

[b,c]Means in each row with different superscripts are different, $P<.05$.

TABLE VII

EFFECT OF FAT LEVEL ON RATE OF GAIN[a]

| Variables | Treatment 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| % Choice White Grease | 0 | 4 | 8 | 12 |
| Number of pigs | 6 | 6 | 5 | 5 |
| Week 1 ADG, kg/day | .06±.04 | .03±.04 | .01±.04 | -.04±.04 |
| Week 2 ADG | .30±.04 | .27±.04 | .22±.04 | .22±.04 |
| Week 3 ADG | .44±.04 | .43±.04 | .48±.04 | .39±.04 |
| Week 4 ADG | .57±.04 | .53±.04 | .62±.04 | .56±.04 |
| Week 5 ADG | .61±.04 | .60±.04 | .66±.04 | .53±.04 |

[a]Week is included in the model for analysis of data from blocks five and six.

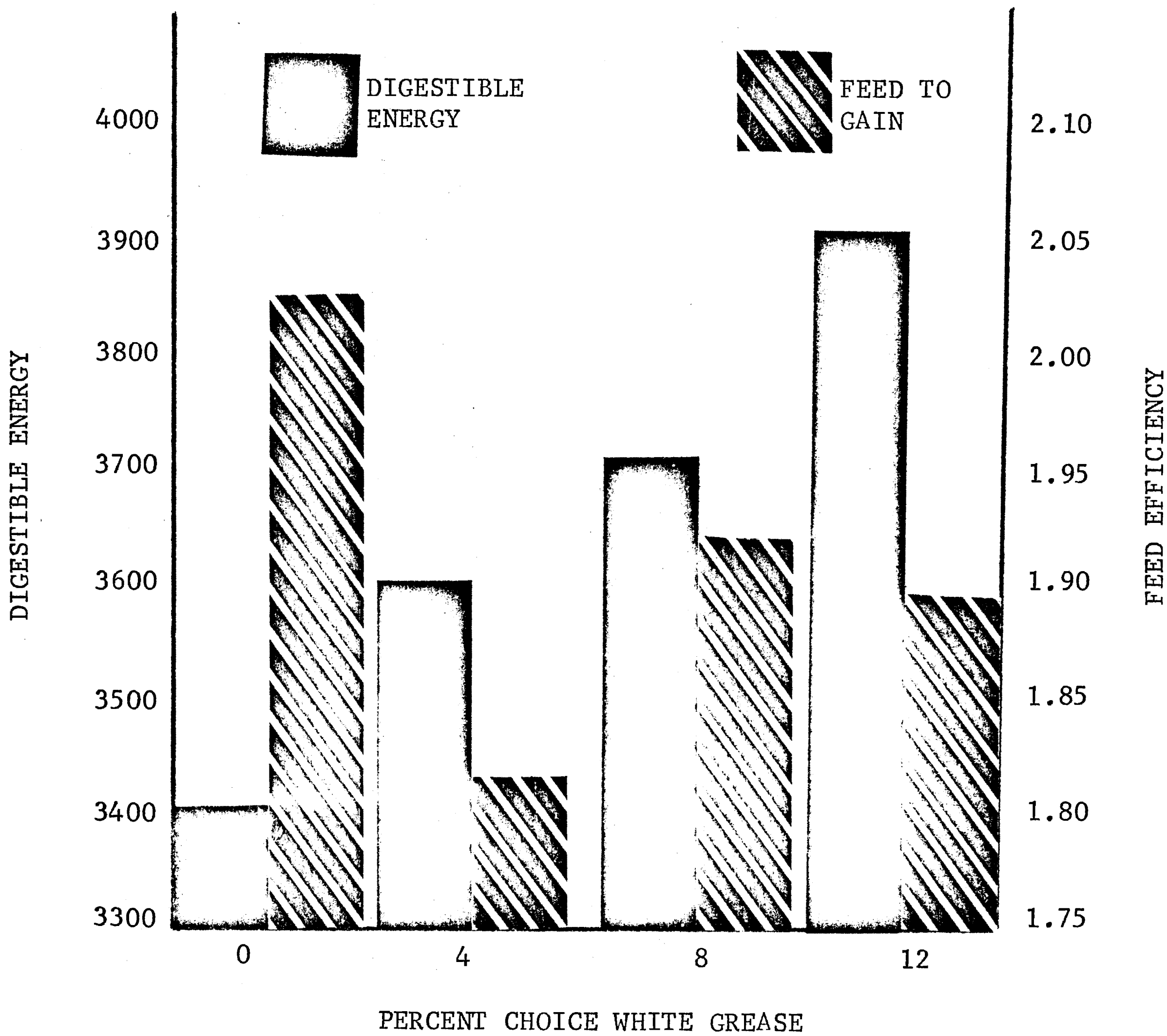


Figure 1. A Comparison of Digestible Energy (Kcal/kg) Content of the Ration and Amount of Feed Required Per Unit Gain for the Entire Five Week Feeding Period.

TABLE VIII

EFFECT OF FAT LEVEL ON EFFICIENCY
OF GAIN AND FEED INTAKE

| Variables | Treatment 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| % Choice White Grease | 0 | 4 | 8 | 12 |
| Digestible energy (Kcal/kg of feed) | 3410 | 3578 | 3747 | 3915 |
| Total feed efficiency[a] (kg feed/kg gain) | 2.03±.07 | 1.82±.07 | 1.92±.07 | 1.89±.07 |
| Total feed efficiency[b] | 2.23±.61 | 2.37±.61 | 2.81±.68 | 1.56±.68 |
| Week 1[b] | 2.39±3.08 | 4.58±3.08 | 6.22±3.44 | 1.40±3.44 |
| Week 2 | 2.92±.78 | 2.20±.78 | 3.14±.87 | 1.51±.87 |
| Week 3 | 1.88±.15 | 1.67±.15 | 1.47±.16 | 1.59±.16 |
| Week 4 | 1.98±.10[c] | 1.76±.10[c,d] | 1.61±.11[d] | 1.51±.11[d] |
| Week 5 | 1.98±.13 | 1.63±.13 | 1.62±.14 | 1.76±.14 |
| Kcal/kg gain[a] | 6926 | 6497 | 7180 | 7405 |
| Kcal/kg gain[b] | 7603 | 8468 | 10541 | 6090 |
| Total feed consumed[a] | 28.09±1.05[c] | 24.60±.09[d] | 26.23±.109[c,d] | 22.51±1.13[e] |

[a]Week is not included in the model for analysis of data from blocks one through six.
[b]Week is included in the model for analysis of data from blocks five and six.
[c,d,e]Means in each row with different superscripts are different, P<.05.

fat in the diet. Energetic efficiency was 6926, 6497, 7180 and 7405 Kcal/kg gain for the 0, 4, 8 and 12 percent fat diets, respectively. When energetic efficiency was analyzed for blocks five and six including week in the model, no significant ($P>.64$) treatment effects were found, however, there was a significant ($P<.0001$) block by week interaction.

Whether or not the early weaned pig is capable of efficiently utilizing fat as a dietary source of energy is poorly understood. In contrast to the results of this trial, several trials conducted by Allee et al. (1971a,b) utilizing isocaloric diets containing tallow or lard in which the calorie:protein ratio was held constant indicate that there is an increase in gain and pigs appeared to be more efficient when percent fat in the diet was increased. Work conducted by Cline et al. (1977) also utilizing isocaloric diets in which the calorie:protein ratio was held constant substantiates the findings of Allee et al. (1971a,b). However, Scherer et al. (1972; 1973b) conducted two studies using isocaloric diets with varying levels of lard substituted for dextrose on a caloric basis. As a result of these trials, Scherer et al. (1972; 1973b) have suggested that the early weaned pig cannot utilize lard for weight gain as efficiently as dextrose. In an additional trial conducted by Allee et al. (1971a) in which no diluent was used and energy density increased with percent fat in the diet, a trend toward an increase in ADG and a significant improvement in feed efficiency was observed with an increase in percent fat in the diet. Generally, in studies where fat was substituted for a dietary component on a weight rather than caloric basis (Peo et al., 1957; Eusebio et al., 1965; Leibbrandt et al., 1967; Frobish et al., 1969, 1970; Leibbrandt et al., 1975), the young pig was unable to efficiently utilize fat as an energy source.

The effect of level of fat on the performance of early weaned pigs is also unclear. Allee et al. (1972) demonstrated that adding increasing levels of fat in the diet with the calorie:protein ratio held constant did not significantly alter daily gains, feed efficiency or metabolizable energy required per unit of gain. However, Eusebio et al. (1965) and Peo et al. (1957) have observed that an increase in level of fat in the diet did not improve feed efficiency and in general tended to decrease rate of gain. Calorie:protein ratio was not held constant in either of these studies. Frobish et al. (1969) conducted a trial in which nutrient intake other than energy intake was equalized when fat was added at increasing levels in the diet. This research group concluded that protein and other nutrient intake were not limiting efficient utilization of fat.

Feed intake was affected by level of dietary fat (Table VIII). Intake for the control ration was greater ($P<.03$) than for the 4 and 12 percent fat diets. Pigs fed the 8 percent fat ration consumed more ($P<.02$) feed than those fed the 12 percent fat ration. Increasing dietary fat level resulted in a linear reduction ($P<.003$) in feed consumption with an increase in percent fat and consequently energy density, in the diet. Total estimated feed consumption was $28.09 \pm 1.05$, $24.60 \pm 1.09$, $26.23 \pm 1.09$ and $22.51 \pm 1.13$ kg for the 0, 4, 8 and 12 percent fat diets, respectively. Accuracy of estimates of feed intake may have been influenced by level of fat in the diet. Considerable bridging occurred when feeding the 12 percent fat ration and these pigs could not waste as much feed as those on the lower fat diets.

Fatty acid composition of the dietary fat may be an additional factor that influences the ability of the early weaned pig to efficiently utilize supplemental fat. Choice White Grease (Table V) is a commercially available high quality animal fat that is very similar to lard in fatty acid composition. It has been shown that pigs fed lard generally have poorer performance than those fed other sources of dietary fat (Eusebio et al., 1965; Leibbrandt et al., 1967). Individual fatty acids appear to be utilized to a different extent by the young pig and combinations of fatty acids may influence the utilization of a given fatty acid (Sewell and Miller, 1965).

The ability of the early weaned pig to efficiently utilize a supplemental dietary fat may be influenced by source of fat, level in diet, age of pig and other unidentified factors. On the basis of this trial and the lack of improvement in overall feed efficiency and average daily gain with an increase in percent fat in the diet, it would not appear advantageous to add Choice White Grease to early weaned pig diets.

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TABLE IX

LEAST SQUARES ANALYSIS OF VARIANCE
FOR FEED EFFICIENCY

| Source | DF | Mean squares | | |
|---|---|---|---|---|
| | | Day 0 to 20 | Day 0 to 14 | Day 14 to 20 |
| Block | 1 | 83849.1 | 786824.2 | 5445412.7 |
| Treatment | 3 | 698914.4 | 280207.7 | 2163431.0 |
| Block x treatment | 3 | 417670.1 | 311739.7 | 1270238.8 |
| Error | 14 | 227846.7 | 219544.7 | 1475614.2 |

TABLE X

LEAST SQUARES ANALYSIS OF VARIANCE
FOR AVERAGE DAILY GAIN

| Source | DF | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | Day 0 to 20 | Day 0 to 14 | Day 14 to 20 | Day 0 to 7 | Day 7 to 14 |
| Block | 1 | .0000269 | .0011236* | .0037140 | .0007134 | .0016267 |
| Treatment | 3 | .0008141* | .0002890 | .0036763* | .0000356 | .0008773 |
| Block x treatment | 3 | .0003732 | .0002827 | .0009972 | .0001122 | .0011416 |
| Error | 14 | .0001732 | .0002099 | .0011246 | .0003713 | .0005062 |

*P<.05.

TABLE XI

LEAST SQUARES ANALYSIS OF VARIANCE FOR FEED EFFICIENCY AND AVERAGE DAILY GAIN[a]

| Source | DF | Mean squares | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Feed Efficiency | ADG Week 1 | ADG Week 2 | ADG Week 3 | ADG Week 4 | ADG Week 5 | Total ADG |
| Block | 5 | 0.19347* | 0.07984** | 0.06632** | 0.30152** | 0.19912** | 0.07219** | 0.06835** |
| Treatment | 3 | 0.13810 | 0.03541* | 0.00967 | 0.01718 | 0.00271 | 0.01245 | 0.00989 |
| Block x treatment | 15 | 0.07294 | 0.00652 | 0.00353 | 0.00568 | 0.01412 | 0.01010 | 0.00200 |
| Error | 44 | 0.08183 | 0.01064 | 0.00791 | 0.01722 | 0.01033 | 0.01198 | 0.00564 |

[a]Blocks 1 through 6.
*P<.05.
**P<.01.

TABLE XII

LEAST SQUARES ANALYSIS OF VARIANCE
FOR ENERGETIC EFFICIENCY[a]

| Source | DF | Mean squares |
|---|---|---|
| Block | 5 | 2615777.2* |
| Treatment | 3 | 2458479.4 |
| Block x treatment | 15 | 1022020.6 |
| Error | 44 | 1089754.6 |

[a]Blocks 1 through 6.
*$P<.05$.

TABLE XIII

LEAST SQUARES ANALYSIS OF VARIANCE
FOR TOTAL FEED CONSUMPTION[a]

| Source | DF | Mean squares |
|---|---|---|
| Block | 5 | 229.97308* |
| Treatment | 3 | 93.72387* |
| Block x treatment | 15 | 8.84567 |
| Error | 44 | 19.67589 |

[a]Blocks 1 through 6.
*$P<.01$.

TABLE XIV

LEAST SQUARES ANALYSIS OF VARIANCE FOR AVERAGE DAILY GAIN, FEED EFFICIENCY AND ENERGETIC EFFICIENCY[a]

| Source | df | Mean squares | | |
|---|---|---|---|---|
| | | ADG | Feed efficiency | Energetic efficiency |
| Block | 1 | 0.34685** | 35.31676 | 479045757.02 |
| Treatment | 3 | 0.02590* | 6.53457 | 836728508.00 |
| Week | 4 | 1.26877** | 14.45159 | 196127362.45 |
| Block x treatment | 3 | 0.00395 | 8.77794 | 112518719.12 |
| Block x week | 4 | 0.07206** | 72.43696** | 954685877.20 |
| Treatment x week | 12 | 0.00551 | 5.30804 | 73034645.50 |

[a] Blocks 5 and 6 only.
*P<.05.
**P<.01.

TABLE XV

LEAST SQUARES MEANS FOR AVERAGE DAILY GAIN, FEED EFFICIENCY AND ENERGETIC EFFICIENCY[a]

| | ADG, kg | | Feed efficiency, kg feed/kg gain | | Energetic efficiency, Kcal/kg gain | |
|---|---|---|---|---|---|---|
| | Block 5 | Block 6 | Block 5 | Block 6 | Block 5 | Block 6 |
| Week 1 | -0.03±.03 | 0.05±.03* | -0.19±1.07 | 7.35±0.97** | -605±3852 | 26873±3477** |
| Week 2 | 0.16±.03** | 0.34±.03** | 3.37±1.07** | 1.58±0.97 | 12144±3852** | 5798±3477 |
| Week 3 | 0.34±.03** | 0.53±.03** | 1.77±1.07 | 1.56±0.97 | 6448±3852 | 5700±3477 |
| Week 4 | 0.48±.03** | 0.66±.03** | 1.76±1.07 | 1.69±0.97 | 6391±3852 | 6170±3477 |
| Week 5 | 0.63±.03** | 0.56±.03** | 1.62±1.07 | 1.89±0.97 | 5903±3852 | 6932±3477* |

[a]Block 5 and 6 only.
*P<.05.
**P<.01.

VITA 2

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