EFFECTS OF SOURCE AND LEVEL OF SUPPLEMENTAL ENERGY ON REPRODUCTIVE PERFORMANCE OF SOWS

by

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GENERAL INTRODUCTION

Anestrus and the extended weaning to breeding interval are major problems facing swine producers as they strive to maximize sow productivity. Failure to breed seems to be greater for primiparous than for multiparous sows, especially during the summer and early fall.

MacLean (1969) defines an infertile sow as one which fails to show estrus within 14 days postweaning. Using this definition, he found that the overall infertility rate in normal herds was up to 26%, but could increase to 36% for primiparous females.

Dagorn and Aumaitre (1979) reviewed reasons for sow culling on French farms. They found 31% of the sows were culled due to a failure to breed after one or several matings and 5.4% were classified as anestrus. Forty-nine percent of the culling occurred in sows that had less than four litters, with the major percentage (21.2%) being gilts after their first litter. The summer months (June, July, and August) showed the highest percentage of culling for breeding failure (35%), with January being the lowest (27%). These findings indicate that season and parity influence sow reproductive efficiency.

In reviewing the causes of reproductive failure in swine, Rasbech (1969) found that a reduction of protein supplementation prolonged the interval from weaning to rebreeding. Fahmy (1981) suggested three major causes of variation in the length of the weaning to estrus interval are genetics, nutrition, and management. Genetics may have a minor role due to the low heritability of reproductive traits. Therefore, nutrition and management appear to be the major areas that influence the reproductive efficiency of sows.

REVIEW OF LITERATURE

Before combating the anestrous behavior in the sow, one needs to examine all potential causes of this phenomenon. A search of the available literature indicates that stress, "silent" estrus, hormone imbalances, lactation length, season of year, parity, breed of sow, lactation weight loss, and feeding levels during lactation and postweaning can influence the interval length between weaning and remating.

Effects of Stress and "Silent" Estrus

Nursing a litter of pigs is a stressful situation for the sow, especially for the primiparous females. The constant demands on the sow may open the way for a low level infection resulting in a sickness without any noticeable symptoms. This unseen sickness may be the cause of delayed return to estrus, although the results of four studies (Fahmy, 1981) show that antibiotics had very little effect on reducing the weaning to estrus interval.

The high incidence and character of the cystic follicles in first parity sows suggests that the poor reproductive performance is stress-associated. Karlberg (1980), in studying factors affecting postweaning estrus in the sow, found that the ovaries of 38.5% (10/26) of the primiparous sows with postweaning estrus failure lacked corpora lutea, while the multiparous sows showed only 13% (3/23) failure. This difference can be attributed to the greater stress of the suckling period on primiparous sows.

"Silent" estrus (quiet ovulation) is the occurrence of ovulation without overt estrus. Slaughterhouse investigation of first parity sows failing to show estrus activity within 18 days of weaning, revealed that most sows had ovulated and developed normal corpora lutea (Love, 1979). Apparently, a large percentage of sows with prolonged weaning-to-estrus intervals are actually experiencing a "silent" estrus soon after weaning. This "silent" estrus may be the cause of the prolonged interval, or it may be that the sows which do not exhibit estrus within 14 days postweaning are actually anovulatory (BeVier et al., 1981).

Effects of Hormone Imbalances

The failure to return to estrus within 28 days postweaning suggests a lack of adequate gonadotrophic hormone stimulation of the ovaries (Dyck, 1971). This failure could be attributed to many factors including stress, lactation effects, and nutrition.

Blood hormone levels in weaned primiparous sows were evaluated by Aherne et al. (1976). They found the mean plasma LH concentration to be low in all animals at weaning with an initial peak (usually small) at 1-3 days postweaning. A second peak, associated with estrus, usually occurred 3-5 days after the first peak, with the highest mean concentrations being observed on the day of estrus. The mean plasma FSH concentrations were highest on the day of weaning and the first day after weaning and then declined until estrus when a slight increase was observed. In the sows which showed estrus within 5-10 days of weaning, the plasma FSH concentrations were either high at weaning or peaked on day 1 after weaning. The mean estrone and progesterone concentrations did not change following weaning. Mean estradiol concentrations were low at weaning, began to increase by day 3 after weaning, reached peak levels during the 2 days prior to estrus and declined on the day of estrus. The patterns of plasma FSH, LH, and estradiol were different in sows that failed to show an early post-weaning estrus, when compared to those sows showing estrus.

Effects of Lactation Length

There is a variety of opinions regarding the role of lactation length in the length of the weaning-to-estrus interval. Moody and Speer (1971) found that lactation length did not have a consistent effect on the interval to first estrus. Hays et al. (1978) found the time required for sows to exhibit estrus was decreased quadratically with increasing length of lactation. However, length of lactation had no significant effect on percent of sows showing estrus.

Early weaning (less than 10 d) appears to have an effect on the weaning-to-breeding interval. Svajgr et al. (1974) observed that the average number of days from weaning to estrus decreased linearly (10.1 to 6.8 d) as the lactation interval lengthened (from 2 to 35 d). Varley and Cole (1976) reported the interval from weaning to remating to be significantly shorter following a 42-day lactation (4.5 d) than for a 10-day lactation (8.2 d). In France, an adverse effect on the weaning to conception interval was noticed when piglets were weaned before 10 days of age, and again when the suckling period exceeded 50 days (Aumaitre et al., 1976).

Effects of Season of Year

Summer infertility in sows, especially primiparous, is characterized by longer intervals from weaning to first estrus and conception. This postweaning delay in the onset of estrus is most pronounced from July through September, with some problems also observed in June and October (Aumaitre et al., 1976; Hurtgen et al., 1980; Karlberg, 1980; Szarek et al., 1981).

Noting that the average length of the weaning-to-conception interval was 15 to 20 days between October and June, Aumaitre et al. (1976) found it to increase to 26-30 days during the summer months. In analyzing eight herds in Iowa and Minnesota, Hurtgen et al. (1980) found an increase in postweaning anestrus of more than 30 days duration during the months of July, August, and September. Szarek et al. (1981) found that the percentage of sows in estrus within 7 days after weaning was lower during June through September (66%) than during April, May, or October (88%).

Hot weather and increasing periods of daylight are two possible explanations for this seasonal anestrus occurring during the summer. As the air temperature increases, the body temperature and respiration rate of the pig will increase (Heitman and Hughes, 1949). This discomfort results in a decrease in feed consumption as well as a lowering of feed utilization. These nutritional deficiencies could be causing the anestrous behavior through weight loss and depletion of body reserves. Increasing periods of daylight also appear to have a detrimental effect on the postweaning interval in sows. Hurtgen et al. (1980) report that the frequency of postweaning estrus began to decline prior to the onset of hot weather and during periods of increasing daylight.

Effects of Parity of the Sows

The effects of summer infertility are greater in the primiparous sow than in the multiparous sow. Szarek et al. (1981) found the percentage of primiparous sows in estrus within 7 days after weaning to be considerably lower than in the multiparous sows (48 vs 75%). The postweaning delay in the onset of estrus was more obvious in primiparous sows than in multiparous (Hurtgen et al. 1980), with the maximum interval length being between the first and second litter, and declining with increasing parity (Aumaitre et al., 1976). MacLean (1969) observed in his study of non-infectious infertility in sows, that the period following first lactation, delayed onset of heat was more common than failure of conception. BeVier et al. (1981) reported that 61.8% of the primiparous sows observed showed estrus by 14 days postweaning, with the remainder taking as long as 90 days.

Effects of Breed of Sow

There appears to be a breed difference in age at puberty (Dyck, 1971; Burger, 1952). In a comparison of different breeds of sows, Dyck (1971) found Yorkshire sows returned to estrus more quickly than did Lacombe sows (5.5 vs. 14.3 d) after a 42-day lactation. Following a 56-day lactation, Large Black sows returned to estrus after 16.1 days whereas Large White sows returned in just 7.8 days (Burger, 1952). Not only is there differences between breeds, but within breeds as well. Aherne et al. (1976) report that following a 3-week lactation, Lacombe sows returned at 6.6 days, considerably less than the 14.3 days observed by Dyck (1971).

Crossbred sows have a shorter weaning-to-conception interval than do purebreds (Aumaitre et al., 1976; Fahmy et al., 1979). A heritability estimate (full-sib analysis) of 0.25 ± 0.10 is given for the weaning-to-estrus interval in crossbred sows (Fahmy et al., 1979). One can conclude from this heritability estimate that improvements in the weaning-to-estrus interval of sows can be made mainly through improving their environment and management.

There are indications that some breeds need a higher plane of nutrition than others. MacLean (1969) noted differences between Landrace, Large White, and Saddleback sows in incidences of infertility and body weight changes when on similar feeding systems. Dyck (1971) indicates a difference between Yorkshire and Lacombe sows in the level of nutrition needed to induce gonadotrophic release and an early return to estrus after weaning.

Effects of Lactation Weight Loss

Excessive loss of weight during lactation, followed by an inability to regain weight quickly after weaning has been shown to be correlated with infertility (MacLean, 1969). Animals which continue to lose body weight, particularly those showing emaciation, often never return to estrus. A reduced feed intake in the last week of lactation significantly increases the weight loss between birth and weaning at 6 weeks (Brooks and Cole, 1973). Reese et al. (1984) observed that the weaning weights of pigs on sows fed 8 Mcal ME/day (Lo) during lactation were the same as those pigs on sows fed 16 Mcal ME/day (Hi). Catabolism of body tissues apparently occurred in the sows fed the Lo diet to compensate for their energy deprivation. This is in agreement with the results of deLange et al. (1980). They observed that while feeding level had no effect on milk energy, when expressed on metabolic weight basis, it did have a significant effect on the amount of energy taken from the body of lactating sows.

Although the sows fed the Lo diets (Reese et al., 1984) lost more weight and backfat than the sows on the Hi diet, there were no significant differences observed in weight loss during lactation when the sows returning to estrus on the Lo diet were compared to those on the Lo diet not returning to estrus by 14 d postweaning. This would seem to suggest that little relationship exists between sow weight loss during lactation and the interval between weaning and first estrus. However, when body fat loss became severe enough the occurrence of postweaning estrus was affected. It was further noted that while fewer sows fed the Lo energy lactation diet expressed estrus by 14 d postweaning than those fed the Hi energy diet, the sows fed the Lo diets exhibited estrus even under situations of substantial body weight and fat losses during lactation.

Fat reserves of a sow are greatest at farrowing of the first litter and fat losses during the subsequent lactation can be considerable (Whittemore et al., 1980). Lowered feed intakes may further accentuate these liveweight and fat losses of sows in their first lactation. These factors along with the selection of leaner gilts may result in sows being in very poor condition with markedly reduced fat reserves after weaning of the first litter (King, 1982).

Brooks et al. (1975) reported that in primiparous sows considerable weight loss during lactation may influence the subsequent reproductive potential resulting in poor reproductive performance. Sows experiencing large weight and backfat losses during lactation had a higher incidence of delayed estrus following weaning than those maintaining their weight and backfat due to the severe depletion of their body reserves (Reese et al., 1982).

Total weight loss by the sow is affected by the feeding level during lactation as well as the weaning-to-remating period. Varley and Cole (1976) reported that weight change during the weaning-to-remating period is affected not only by the feeding level of that period, but can be influenced by the feeding level of a previous lactation period as well.

Hardy and Lodge (1969) noted a marked weight loss during the weaning-to-breeding period, especially in the medium- and high-plane fed sows which had maintained their weight during lactation. They also reported that weight change in lactation, weight change from parturition to present estrus and the percentage weight changes over these periods will significantly influence the number of corpora lutea. Thus if increased production is desired, excessive weight loss needs to be avoided because of the inverse relationship with the number of ova shed and with the delay of postweaning estrus.

Effects of Feeding Level

Although sows can continue to reproduce on low feed intakes, Elsley et al. (1968) found a gradual depletion of body reserves under these conditions which eventually leads to a situation where the animal is unable to reproduce normally. In studying sows over three lactation periods, O'Grady et al. (1975) found that the reduction in fat reserves was linearly correlated with the dietary energy intake of the sows. In this particular study, the sows receiving the lowest energy intake (12-13 Mcal DE/d) in lactation lost nearly 80% of their initial weight of subcutaneous fat, while those sows receiving a high energy intake (20-21.5 Mcal DE/d) lost only 20%.

A restriction of energy intake during lactation, whether from limit feeding, low energy density of the diet, or depressed feed intake due to high environmental temperatures, if severe enough will affect the return to estrus in sows. However, a high plane of feeding following weaning may alleviate the adverse effects of lactation weight loss. In multiparous sows, reproductive performance is not significantly influenced by the level of feeding received during the weaning-to-remating interval (Brooks et al., 1975). Studies conducted by Hurtgen et al. (1980), Szarek et al. (1981), and Reese et al. (1982) concur in suggesting that multiparous sows may differ from primiparous sows in their energy requirements for optimum return to estrus, with the primiparous sows requiring the higher level.

Increasing the level of energy in the diet during late gestation, lactation, and immediately following weaning gives mixed results. Cox et al. (1983), King (1982), and Reese et al. (1982) all report an improvement, as indicated by a shorter weaning-to-breeding interval, when the energy level of the diet is increased. This improvement is particularly noted in the summer, but does not seem to affect the interval in the winter. Restricting the energy intake of sows by restricting their feed intake results in a significant decrease in the percent showing estrus by day 8 after weaning (King, 1982).

Other studies indicate that the level of feeding (energy) has no significant effect on the length of the weaning-to-breeding interval. Adam and Shearer (1975), Varley and Cole (1976), Frobish et al. (1966), Elsley et al. (1968), and Pollmann et al. (1984) all indicate that the interval between weaning and first postweaning estrus was not influenced by varying the energy level either during lactation or immediately after weaning. While there appeared to be no differences between sows fed the fat and control diets on rebreeding performance and average number of days to estrus, Pollmann et al. (1984) reported a slight improvement in the farrowing rate and litter size in the subsequent farrowing when primiparous sows were fed additional fat until breeding.

Although the results of adding supplemental energy to the lactation diet are somewhat variable, sows appear to have more body condition postweaning. Reese et al. (1982) report that sow weight and backfat loss during lactation decreased linearly as energy intake increased. When sows are fed a low energy diet, there is a substantial loss of backfat by the sows indicating that adipose tissue probably accounts for a major proportion of the weight loss. These losses agree with previous research by O'Grady et al. (1975). Miller et al. (1971) suggested that lactating sows incorporate fatty acids of dietary origin into milk production preferentially to those from body storage. This may account for the greater loss of backfat in sows fed a low energy diet when compared to sows fed a diet with added fat.

Effects of Energy Level During Postweaning Interval

Despite the variability of the length of the postweaning interval, one can assume that there is some benefit to be obtained by increasing the amount of energy consumed by the sow. MacLean (1969) reports that any sow which does not regain body weight at a rate of at least 0.14 kg/d from weaning to one month postweaning is likely to be infertile.

Fasting after weaning has been a common practice in many swine operations. However, research indicates that fasting has no significant effect on the number of days to estrus after weaning (Allrich et al., 1979; Aherne et al., 1976; Brooks and Cole, 1973; King,1974), and has a detrimental effect on the subsequent litter size (Adam and Shearer, 1975). Increasing the energy level for one feeding period, the other extreme in feeding management, does not appear to have an effect on reproductive performance in the sow.

Tribble and Orr (1982) showed no difference in days from weaning to estrus for sows fed 3.6 vs 1.8 kg/d from weaning to estrus. This is in agreement with the work of

Dyck (1972), Brooks et al. (1975), and Varley and Cole (1976). In their study, Tribble and Orr reported that 3.6 kg/d is more than most sows will consume immediately after weaning, and some sows may have difficulty consuming 1.8 kg. The extra feed (over 1.8 kg) consumed by the primiparous sows from the 3.6 kg/d treatment tended to decrease the days to estrus by .7 d for each 1.4 kg increase in feed, perhaps indicating a higher energy need by the younger sows.

A continuous high plane of feeding (protein as well as energy) after the lactation period and until mating is important for estrus expression in breeding sows. First estrus was shown to be delayed three days in herds feeding at low levels after weaning as compared with herds feeding at high levels (Karlberg, 1980). Ad libitum feeding during lactation followed by a high level of feeding immediately after weaning can contribute to a greater percentage of primiparous sows in estrus within 12 days after weaning, along with a high subsequent farrowing rate (Love, 1979).

Frobish (1970) reported that following withdrawal of AIMAX (an estrus synchronization product) the onset of estrus occurred 1.5 days later in gilts fed a low (2600 kcal/d) energy intake than in those receiving a high (6000 kcal/d) energy intake. This difference between gilts which are still growing is similar to sows in poor body condition postweaning. In some herds, sows that lose a considerable amount of body condition during lactation may benefit from the adoption of a more liberal level of feeding between weaning and remating. It is possible that the effects of factors such as liveweight and body condition may be modified by this postweaning nutrition or management.

Increasing the plane of nutrition between weaning and remating has been shown to reduce the interval to estrus, as well as the variance associated with the onset of estrus. Dyck (1972) reports that the variance was greater ($P<.01$) for the sows fed 2.25 kg/d ($\bar{x}=4.9$, SD=2.17) as compared to those fed 3.75 kg/d ($\bar{x}=4.9$, SD=.91). This indicates that the level of feeding may have affected the consistency with which the sows returned to estrus without influencing the average time.

Although postweaning feed intake appears to have no significant effect on the weaning-to-breeding interval, there is a trend toward increased ovulation rate and thus larger litters when the feeding level is increased (King, 1982; Brooks and Cole, 1972). This increase in fertility shows one beneficial effect of increasing the plane of feeding between weaning and remating. Another example of this increase in fertility was reported by Pollmann et al. (1984). They found that sows fed diets supplemented with dried choice white grease from weaning to first service tended to increase farrowing rate compared to the control group.

Effects of Level and Source of Supplemental Energy

Only limited information is available on the effects of level and source of fat in sow diets on postweaning return to estrus. As discussed earlier, it is apparent that an increased level of feed intake does decrease the weaning-to-breeding interval.

There however has been some work done with younger pigs to determine the effect of various sources and levels of supplemental fat in their diets. Seerley et al. (1978) reported no difference in ADG between diets with 3350 or 3700 kcal ME in the weanling pig. They did find however that the pigs fed 9% fat ate less feed and had a 10% improvement in feed conversion. Allee (1977) noted that adding 6% fat while maintaining a constant calorie:protein (C:P) ratio resulted in increased ADG and improved feed efficiency when compared to diets containing the fat without making the adjustments in the C:P ratio. Cline et al. (1977) showed no difference in the rate of growth or the cumulative gain in animals fed diets which contained fat concentrations ranging from 12 to 14 percent of the total non-protein calories. This is in agreement with Lawrence and Maxwell (1983) who found that gains were not significantly affected by the level of fat inclusion. Research by others has also indicated a drop in feed intake along with an improvement in feed efficiency when adding fat to the growing pigs' diet (Seerley et al., 1964; Allee and Hines, 1972; Allee et al., 1972;

Hines, 1977).

While varying the level of fat does not seem to have an effect on gain, it appears that the source of fat does. Sewell and Miller (1965) noted that pigs receiving corn oil as a source of fat gained slightly faster than pigs receiving diets containing either tallow or lard as the supplemental fat. Allee et al. (1971) also report an increase in ADG and improved feed efficiency with the addition of corn oil. However, this is in contrast to work done by Asplund et al. (1960) and Greeley et al. (1964) which showed a significant reduction in ADG due to the use of corn oil as the source of fat in the growing diet. Tallow, soybean oil, and coconut oil result in a higher gain than lard according to research by Eusebio et al. (1965). When compared to corn oil and lard, coconut oil resulted in greater gains in newborn pigs (Lawrence and Maxwell, 1983). While noting that F/G was negatively correlated (r=-.95) to energy concentration of the diet, Brooks (1972) reported no difference in pig performance due to source of fat.

Effects of Energy Level and Source in Poultry

There has been considerable work done with poultry evaluating the effects of energy level and source in the diet. Feeding thyroprotein (iodinated casein) to pullets will cause a decrease in body weight, much the same as sows experience during lactation. Lillie et al. (1952) reported that the inclusion of 8% lard in the diet resulted in an increase in body weight and feed efficiency, whether the thyroprotein level was high or low.

In general, adding fat to the diet of laying hens will reduce feed consumption and improve feed efficiency. Sell et al. (1979) found the average daily feed intake by hens to be inversely related to the level of yellow grease added to the diets, with the average ME intake per hen per day remaining unchanged. This improvement has been attributed to the influence of fat on the "extra metabolizable calories" (EMC) of rations. Horani and Sell (1977) found that the use of 4% fat caused a larger response in terms of EMC than did the 2% fat level when fed in a corn diet. They also found the influence of fat on the EMC of rations based largely on corn to be more consistent than those with barley or oats. Mateos and Sell (1980) noted that the ME of each carbohydrate fed was increased with each increment of supplemental fat (0-9% added fat), indicating that supplemental fat enhances the utilization of energy from nonlipid dietary constituents. Further studies by Mateos and Sell (1981) are in agreement with these findings. The supplementation of starch- and sucrose-containing diets with yellow grease improved the utilization of energy contained in the non-fat constituents of the diets.

Horani and Sell (1977) hypothesized that the unsaturated fatty acids contained in corn interacted with the relatively low level of dietary saturated fatty acids of animal fat so that total fat absorption was increased beyond that which would have occurred had there been an overwhelming proportion of saturated fatty acids. As a consequence, the ration ME is increased more than expected on the basis of the recognized ME value of animal fat.

Young (1961) reports that source of fat affects the utilization of the fat in the chick. Chicks fed beef tallow and beef tallow fatty acids showed poorer conversion than with soybean oil, corn oil, lard (and their fatty acids), yellow grease, and hydrolyzed animal and vegetable fat. The fatty acids in soybean oil, corn oil, and lard appear to be well utilized by the chick.

Digestibility of Fat Sources

The digestibility of supplemental fat sources in sows is not well documented in the literature. Some work has been done in the young pig, but most of the digestibility information for nonruminants is from studies with rats and poultry.

Using rats as the test animal, Carroll (1958) found that short-chain (up to C_{10})

saturated fatty acids were completely digested. With the digestibilities of fatty acids with chain lengths of C_{10} to C_{18} decreasing progressively with very small amounts of the C_{18} and higher fatty acids being absorbed. He also found that the digestibilities of the mono-unsaturated fatty acids were approximately the same as those of saturated fatty acids with 6 less carbons. In another study using rats, Cheng et al. (1949) reported the presence of Ca and Mg in the diet did not influence the digestibility of low-melting fats. However, it markedly decreased the digestibility of higher-melting simple triglycerides and hydrogenated fats. This effect of Ca and Mg is a progressive one, being greater as the proportion of these salts increased in the diet.

Energy availability may change under certain conditions due to the occurrence of interactions between Ca, dietary fats, and other diet components. The true metabolizable energy (TME) value of a fat is affected by the composition of the basal diet. Sibbald and Price (1977), using chicks, found that a higher level of Ca corresponds to a lower TME value for the fat. The level of dietary fat inclusion also appears to have a small but detectable effect on the TME value of tallow and, to a lesser degree, soybean oil. These workers go on to report that a change of 1 kcal/g in the TME of a fat alters the TME of a finished feed by only 0.01 kcal/g for each 1% of dietary fat inclusion.

Young (1961) noted that ME and absorbability values of oils and fats appear to be reliable measures for expressing the energy which can be utilized by the chick. He also reported that a decrease in the utilization of fat with hydrolysis was greater for animal fats than for vegetable oils. The hydrolysis of beef tallow caused a decrease in the absorbability of both palmitic and stearic acids, and only palmitic acid was decreased in hydrolyzed lard. There was a decrease in the absorbability of stearic acid due to the hydrolysis of corn and soybean oils.

It was reported by Sibbald and Kramer (1978) that the grain used in the basal diet also has an effect on the TME value for tallow. Diets containing corn yielded greater TME values than did diets containing wheat. The level of inclusion also affects the TME values of tallow, with a decrease in the TME as the level of tallow increased. Another study by Sibbald (1978) indicated that adding soybean oil increases the TME value of tallow in a diet, but the addition of lard has little or no effect when combined with the tallow. Greater responses per unit of weight are achieved through small additions of soybean oil to tallow than with large additions.

The increase in ME value, associated with fat supplementation, may be partially explained as an interaction among the dietary fatty acids. Sell et al. (1979) reported that the relatively high ME values of yellow grease observed in their study occurred in diets where the linoleic acid contributed by corn and other ingredients increased the linoleic acid concentration of the total diet fat as compared with that present in the yellow grease. The amount of unsaturated fatty acids present may influence the utilization of the saturated fatty acids (Young, 1961). The degree of utilization of saturated fatty acids increases as the amount of unsaturated fatty acids in the mixtures is increased.

Mateos and Sell (1981) noted an improved digestibility for yellow grease, possibly resulting from the beneficial effect of fatty acid synergism on fat utilization. Leeson and Summers (1976) report that this synergism between the fatty acids of supplemental fats and the fatty acids inherent in the other ingredients may be involved in giving relatively high ME values. The unsaturated fatty acids of the fats in grains apparently enhance the absorption of relatively saturated fatty acids from the supplemental animal fats.

Not only does the addition of fat increase the energy available to the chick, but the rate of passage through the digestive tract is decreased as well (Mateos et al., 1980). This slower rate of passage could be allowing for a greater digestibility of the nutrients.

Whether or not these data from chick studies can be applied to other nonruminants, like the pig, remains to be seen. Some studies conducted in the young pig show that the source of fat does seem to influence its digestibility. The digestibility of coconut oil is higher than soybean oil (Eusebio et al., 1965), corn oil appears to be more digestible than tallow or lard (Sewell and Miller, 1965), and a partially hydrolyzed fat containing 40% free fatty acids was higher than butter, coconut oil, lard, or corn oil (Frobish et al., 1970).

As with the chick, it appears that individual fatty acids may be utilized to different extents by the young pig, and combinations of fatty acids may influence the utilization of a given fatty acid (Sewell and Miller, 1965). Another possible explanation of why the source affects fat digestibility is that the differential utilization of dietary fat may be partially due to its fatty acid composition (Lawrence and Maxwell, 1983).

Eusebio et al. (1965) and Lawrence and Maxwell (1983) noted that the young pig does not efficiently utilize fat composed of long chain fatty acids, ($\geq C_{18}$), but those fats which have a shorter average chain length appear to be more readily digested, resulting in increased ADG and improved feed efficiency. Sewell and Miller (1965) report a significant decrease in the absorbability of stearic acid as compared to palmitic, oleic, and linoleic acids. Apparently, the absorbability of stearic acid is depressed when fed in combination with high amounts of unsaturated fatty acids, however, the high absorbability of oleic and linoleic acids was quite consistent regardless of the amount or type of fatty acids present in the diet.

Since the results of work done in the young pig closely parallels that of the chick, perhaps the same conclusions can be applied to the sow. However, the digestibility of various fat sources by sows has not been evaluated.

INTRODUCTION

Anestrus and the extended weaning to breeding interval are major problems facing swine producers as they strive to obtain maximum production from their sows. Failure to breed seems to be greater for primiparous than for multiparous sows, especially during the summer and early fall.

MacLean (1969) defines an infertile sow as one which fails to show estrus within 14 days postweaning. Using this definition, he found that the overall infertility rate in normal herds was up to 26%, but could increase to 36% for primiparous females.

Dagorn and Aumaitre (1979) reviewed reasons for sow culling on French farms. They found 31% of the sows were culled due to a failure to breed after one or several matings and 5.4% were classified as anestrus. Forty-nine percent of the culling occurred in sows that had less than four litters, with the major percentage (21.2%) being primiparous females. They also reported that the summer months showed the highest percentage of culling for breeding failure (35%), with January being the lowest (27%). These findings along with work done by MacLean (1969), Aumaitre (1976), Hurtgen et al. (1980), and Szarek et al. (1980) indicate that season and parity influence sow reproductive efficiency.

Fahmy (1981) suggests genetics, nutrition, and management as being causes of variation in the length of the weaning to estrus interval. Due to the low heritability ($.25 \pm .10$) for the weaning-to-estrus interval (Fahmy et al., 1979), one can conclude that improvements can be made mainly through nutrition and management.

The weaning-to-breeding interval has been shown to decrease with an increased energy intake during late gestation, lactation, and immediately following weaning (King, 1982; Reese et al., 1982; Cox et al., 1983). Other studies (Frobish et al., 1966;

Elsley et al., 1968; Adam and Shearer, 1975; Varley and Cole, 1976; and Pollmann et al., 1984) indicate that the interval between weaning and first postweaning estrus was not influenced by the energy level either during lactation or immediately after weaning.

The trials reported herein were conducted to evaluate the effects of feeding various levels and sources of supplemental energy during lactation and from weaning to rebreeding on sow reproductive performance and nutrient digestibility.

MATERIALS AND METHODS

Three experiments were conducted to evaluate the effects of adding supplemental energy sources to sow diets following weaning. The first experiment compared cornstarch and tallow as supplemental energy sources. The second experiment examined various levels of added tallow. The third experiment evaluated tallow and soybean oil as supplemental energy sources. A digestion study was conducted to determine the apparent nutrient digestibility of soybean oil, an 85% dried animal and vegetable fat product, and an 80% fat product made with choice white grease. In addition, the influence of tallow addition to the lactation diet was also evaluated in the first and third experiments.

General Procedure

The sows used in the lactation studies were assigned at random to the treatments. For the weaning-to-breeding studies, all sows were weaned after a 3-week lactation (range of 16-30 d) and allotted to treatments by weight, backfat, parity and previous treatment (if any). A randomized block design was used for the feeding trials and a two-period crossover design was used for the digestion trial. Data were analyzed statistically using analysis of variance and Duncan's New Multiple Range Test (Snedecor and Cochran, 1980). The sows were housed in individual stalls (53 x 168 cm) in an environmentally controlled gestation barn located at the University Swine Center. Each stall has an individual feeding bowl and a nipple waterer.

With time of weaning being called day 0, all sows were checked for estrus beginning on day 3½. This was accomplished by moving the sows to a 3.7 x 4.3 m pen and introducing a boar. Sows were heat checked in this manner twice daily (9 am and 4 pm) until found in estrus. All sows not showing estrus by day 12 after weaning were considered anestrus and removed from the breeding herd, as they no longer fit the farm's rebreeding schedule.

The diets were prepared at the University Feed Mill and stored in paper sacks. The fat sources and cornstarch were mixed into the feed in 91 kg batches to allow for adequate mixing to occur. The feed was weighed and fed to each sow in the morning, with any refusals removed and recorded after 24 hours. The sows in trials 1 and 2 were fed the experimental diets until they were found in estrus, at which time they were switched to the standard gestation diet. In trial 3, the sows remained on the experimental diets until 30 days postbreeding, when they were switched to the standard gestation diet.

All sows showing estrus were bred twice by artificial insemination at approximately 24 and 36 hours after standing heat was observed. At 18 days postbreeding, each sow was heat checked for 8-days. The sows were pregnancy checked using an ultra sound pregnancy detector[1] at 30 days postbreeding. All pregnant sows were moved to outdoor lots for the remainder of the gestation period.

Farrowing rate, number born alive, and total litter size were monitored in the subsequent farrowing for each of the feeding trials.

In the digestion trial, sows were housed in the individual 53 x 168 cm gestation stalls with a solid concrete floor. Plywood barriers were placed between crates to aid in seperation of feces. Daily feed intake was constant for each treatment (2 kg), and was fed once daily in the morning. Fresh water was supplied via a nipple waterer for 2 h in the morning and 2 h in the afternoon. A pre-test adjustment period of 5 days preceded each collection period. A ferric oxide marker was fed (28 g/sow) at the beginning and end of each collection period. Feces were collected 2 to 3 times daily

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[1] ILIS Pregchek.

and stored in a freezer. The entire fecal collection was dried at 50 C in a forced air oven, weighed and ground in a Wiley mill equipped with a 40-mesh screen.

Urine was collected in covered 19 liter plastic containers, containing 10 ml concentrated HCl, through the use of an indwelling catheter[2] (size 20, 5-cc balloon type) inserted into the bladder. The total volume of urine was weighed daily, with a 5% aliquot taken. Accumulated aliquots were stored at 4 C until analyzed for nitrogen as outlined by A.O.A.C. (1980).

Representative feed and fecal samples were also analyzed for nitrogen, dry matter, fat, and energy according to A.O.A.C. (1980).

The composition of the diets used is given in Tables 1, 2, 3 and 4. All diets were formulated to meet NRC (1979) requirements for the sow, and were fed in a meal form. Tallow additions in the lactation diets were made at the expense of ground sorghum grain.

Trial 1. Thirty-three primparous sows were assigned at random to one of two lactation treatments, basal (control) and basal + 10% tallow, which were fed ad libitum for the last 7 days of the lactation period. Following weaning, the sows were assigned by weight, backfat, and previous lactation treatment to one of three postweaning treatments. The three treatments were: 1) 1.4 kg basal diet (control), 2) control + .73 kg cornstarch, and 3) control + .25 kg tallow. These diets were fed daily (am) from weaning until estrus was detected.

Trial 2. This experiment consisted of two periods (July and August) using the same dietary treatments. The three treatments used were: 1) 1.4 kg basal diet (control), 2) control + .227 kg tallow (14% tallow), and 3) control + .454 kg tallow (25% tallow). These diets were fed daily (am) from weaning until estrus was detected.

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[2]Bardex® Foley Catheters.

TABLE 1. COMPOSITION OF BASAL DIET, TRIAL 1

INGREDIENT	%
SORGHUM GRAIN, GROUND (IFN 4-04-383)	72.60
SOYBEAN MEAL (44%) (IFN 5-04-612)	22.50
DICALCIUM PHOSPHATE (IFN 6-01-080)	2.50
GROUND LIMESTONE (IFN 6-01-069)	1.30
SALT (IFN 6-04-151)	.50
VITAMIN PREMIX[a]	.50
TRACE MINERAL[b]	.10
	100.00

[a]Each kg of premix contained: vitamin A, 880,000 IU; vitamin D_3, 66,000 IU; riboflavin, 990 mg; choline, 88 g; d-pantothenic acid, 2640 mg; niacin, 5500 mg; vitamin E, 4400 IU; vitamin B_{12}, 4.84 mg; menadione dimethylpyrimidinal bisulfite, 550 mg; ethoxyquinone, 6270 mg.

[b]Contained 5.5% Mn; 10% Fe; 1.1% Cu; 20% Zn; 0.15% I; 0.1% Co.

Period I (July) of this experiment was conducted using 37 primiparous sows assigned to one of the three treatments using weight and backfat thickness as allottment criteria. Twenty-two second litter (multiparous) sows and 9 primiparous sows were used during Period II (August). The sows used in this experiment were not on any treatments during the preceding lactation period.

Trial 3. This experiment was divided into two periods (June and July/August). The sows in both periods of this trial were fed one of three treatments: 1) 2.0 kg control diet, 2) 1.8 kg 10% tallow diet, or 3) 1.8 kg 10% soybean oil diet. The sows were fed this diet once daily (am) from weaning until 30 days postbreeding.

In Period I (June), 14 multiparous sows (3^{rd} and 4^{th} parity) and 16 primiparous sows were used. Allottment was based on parity and weight. These sows were not on any treatments during the preceding lactation.

Sixty-four primiparous sows were used in Period II (July and August). They were assigned an ad libitum lactation treatment of the basal diet given in Table 1, or basal + 5% tallow, with feed intake recorded. Following weaning, sows were allotted to one of the same three treatments used in Period I, according to their weight and previous lactation treatment. Seven sows were not used on the postweaning treatments due to poor body condition.

Trial 4. This digestion study was conducted to determine the apparent nutrient digestibility of three fat sources. The fat sources evaluated were soybean oil (SO), an 85% dry animal and vegetable fat (DAV), and an 80% dry fat product made with choice white grease (DCWG). The control diet was a 13.1% crude protein corn-soybean meal diet with 8% corn starch (CONT). Fat sources were added to the control diet to supply 8% added fat. Analysis of the diets is given in Table 5. Twelve sows were used in a crossover design, with three sows per diet in each of two periods. Each period consisted of a 5-day adjustment and a 5-day total collection of urine and feces.

TABLE 2. COMPOSITION OF BASAL DIET, TRIAL 2

INGREDIENT	%
SORGHUM GRAIN, GROUND (IFN 4-04-383)	57.60
SOYBEAN MEAL (44%) (IFN 5-04-612)	22.50
WHEAT STARCH	15.00
DICALCIUM PHOSPHATE (IFN 6-01-080)	2.50
GROUND LIMESTONE (IFN 6-01-069)	1.30
SALT (IFN 6-04-151)	.50
VITAMIN PREMIX[a]	.50
TRACE MINERAL[b]	.10
	100.00

[a]Each kg of premix contained: vitamin A, 880,000 IU; vitamin D_3, 66,000 IU; riboflavin, 990 mg; choline, 88 g; d-pantothenic acid, 2640 mg; niacin, 5500 mg; vitamin E, 4400 IU; vitamin B_{12}, 4.84 mg; menadione dimethylpyrimidinal bisulfite, 550 mg; ethoxyquinone, 6270 mg.

[b]Contained 5.5% Mn; 10% Fe; 1.1% Cu; 20% Zn; 0.15% I; 0.1% Co.

TABLE 3. COMPOSITION OF DIETS, TRIAL 3

INGREDIENT	%		
	Control	Tallow	SB Oil
SORGHUM GRAIN, GROUND (IFN 4-04-383)	80.80	63.26	63.26
SOYBEAN MEAL (44%) (IFN 5-04-612)	15.00	22.00	22.00
TALLOW	-	10.00	-
SOYBEAN OIL	-	-	10.00
DICALCIUM PHOSPHATE (IFN 6-01-080)	1.85	2.10	2.10
GROUND LIMESTONE (IFN 6-01-069)	1.25	1.41	1.41
SALT (IFN 6-04-151)	.50	.56	.56
VITAMIN PREMIX[a]	.50	.56	.56
TRACE MINERAL[b]	.10	.11	.11
	100.00	100.00	100.00

[a]Each kg of premix contained: vitamin A, 880,000 IU; vitamin D_3, 66,000 IU; riboflavin, 990 mg; choline, 88 g; d-pantothenic acid, 2640 mg; niacin, 5500 mg; vitamin E, 4400 IU; vitamin B_{12}, 4.84 mg; menadione dimethylpyrimidinal bisulfite, 550 mg; ethoxyquinone, 6270 mg.

[b]Contained 5.5% Mn; 10% Fe; 1.1% Cu; 20% Zn; 0.15% I; 0.1% Co.

Rate of passage, measured as time from feeding the ferric oxide marker until its first appearance in the feces, was visually observed and recorded. Sows were observed for passage of the marker at 0800, 1200, 1600, and 2000 h. Any passage between these hours was recorded as observed. Sows were not observed between 2000 and 0800 h, and any feces containing marker found at 0800 was recorded as being observed at 0800. Since the sows were sleeping until fed at 0800, it is assumed that these recorded values contain minimal errors.

TABLE 4. COMPOSITION OF BASAL DIET[a], TRIAL 4

INGREDIENT	%
YELLOW CORN, GROUND (IFN 4-02-931)	80.95
SOYBEAN MEAL (44%) (IFN 5-04-612)	15.00
DICALCIUM PHOSPHATE (IFN 6-01-080)	2.00
GROUND LIMESTONE (IFN 6-01-069)	1.00
SALT (IFN 6-04-151)	.50
VITAMIN PREMIX[b]	.50
TRACE MINERAL[c]	.05
	100.00

[a]Santoquin added at 115g/ton as a preservative.

[b]Each kg of premix contained: vitamin A, 880,000 IU; vitamin D_3, 66,000 IU; riboflavin, 990 mg; choline, 88 g; d-pantothenic acid, 2640 mg; niacin, 5500 mg; vitamin E, 4400 IU; vitamin B_{12} 4.84 mg; menadione dimethylpyrimidinal bisulfite, 550 mg; ethoxyquinone, 6270 mg.

[c]Contained 5.5% Mn; 10% Fe; 1.1% Cu; 20% Zn; 0.15% I; 0.1% Co.

TABLE 5. ANALYSIS OF CRUDE PROTEIN, ETHER EXTRACT, AND ENERGY OF EXPERIMENTAL DIETS, TRIAL 4

Diet	Crude Protien,%	Ether Extract,%	Energy, kcal/kg
CONTROL	13.1	2.4	4235
SOYBEAN OIL	13.8	10.0	4596
DRIED ANIMAL & VEGETABLE FAT	14.2	10.6	4689
DRIED CHOICE WHITE GREASE	14.1	10.8	4674

RESULTS AND DISCUSSION

Fat in the Lactation Diet

Trial 1. The influences of tallow addition during the last 7 days of lactation are shown in table 6. Sow performance as indicated by postweaning interval and percent showing estrus was not affected by the addition of tallow. Lactation feed intake, fed ad libitum, remained the same regardless of the diet consumed. This is in contrast to work done in the finishing pig which shows a reduced feed intake with the inclusion of fat in the diet (Seerley et al., 1964; Allee et al., 1972; Allee and Hines, 1972; Allee, 1977; Hines, 1977; Seerley et al., 1978).

Weight loss for the entire 3-week lactation was greater for the sows given the tallow diet than for the sows receiving the control diet ($P<.10$). Since the tallow was fed for only the last 7 days of lactation, it does not seem unusual for this weight loss to occur. However, the large difference between the two diets (4.1 kg) is interesting. Baker et al. (1969) reported that increased weight gain during gestation results in a larger weight loss during the subsequent lactation. This would seem to be the case in this study. The sows were allotted to the lactation treatment at random, with the heavier sows apparently being put on the tallow treatment. These heavier sows then lost more weight than the lighter sows on the control diet.

Piglet survivability (no. weaned/no. on sow at 14 d postfarrowing) was not influenced by lactation treatment. The weaning weights of the pigs did not differ between treatments, but total litter weight at weaning was higher for the tallow diet group (39.2 vs 35.9 kg) due to a numerical increase in the number of pigs weaned per sow. The stress due to this increase in total weaning weight could account for the

TABLE 6. EFFECT OF ADDING TALLOW TO DIET FOR LAST 7 DAYS OF LACTATION ON SOW REPRODUCTIVE PERFORMANCE, TRIAL 1

Level of added tallow	0%	10%	
Digestible energy, kcal/kg	3250.5	3698.8	
Item			SE[a]
No. sows	17	16	
Percentage showing estrus			
≤ 7 d	52.9	68.8	
≤ 12 d	82.4	81.3	
No. sows anestrus	3	3	
Sow performance			
Lact. feed intake, kg/d	4.2	4.3	.1
Daily DE intake, kcal	13,652	15,905	
Sow farrowing wt.[b], kg	157.2	166.2	
Sow weaning wt., kg	143.6	148.5	3.1
Lact. wt. change, kg	-13.6	-17.7	1.6
Postweaning interval, d	6.4	6.4	.6
Farrowing rate[c], %	64.3	38.5	
Subsequent litter size[d]	6.7	7.0	1.4
Litter performance			
Survival rate[e], %	97.8	99.3	
No. weaned	8.3	8.9	.5
Weaning weight, kg	4.4	4.4	.1
Litter weaning wt., kg	35.9	39.2	2.3

[a]Standard error.
[b]Weight of sow ≤ 24 h post farrowing.
[c]Percent of sows cycling which had a subsequent litter.
[d]Number pigs born alive.
[e]Survival rate for day 14 to weaning.

larger weight loss experienced by the sow consuming the tallow diet. This study indicated that there is no difference in the average postweaning interval length. However, there was a slight numerical advantage for the tallow diet when looking at the percentage showing estrus within 7 days after weaning (68.8 vs 52.9%). The subsequent litter size did not appear to be affected by the lactation diet which the sow received.

Trial 3. The influences of tallow addition throughout the entire lactation period are shown in table 7. The results of this study show that again the sows on the tallow diet had a similar feed intake as the control sows. However, in this trial the sows consuming the tallow diet tended to lose less weight than the control group (9.9 vs 13.8 kg). This could be attributed to the fact they were consuming 1612 kcal DE per day more than the sows on the control diet (14,289 vs 12677 kcal DE/sow/day). Survival rate of the pigs was similar for both treatments, with a numerical advantage in favor of the control sows (87.1 vs 81.4%). The control sows weaned slightly more pigs (8.3 vs 7.7) at the same weight, resulting in a heavier litter weaning weight than the sows fed tallow (40.5 vs 37.0 kg). This trial shows the same trend as trial 1, with the sows weaning the heaviest litters showing the largest weight loss.

The postweaning interval was not affected by the treatment, as the average interval length was similar, with no differences occurring in percentage showing estrus at 7 or 12 days. Farrowing rate and the subsequent litter size were similar for both treatments, with a slight numerical advantage for the sows fed tallow.

Energy Source in the Breeding Diet

Trial 1. The effects of the energy source in the diet from weaning to breeding on the reproductive performance of sows are shown in table 8. These diets were fed from weaning until the time of estrus detection. All sows in this trial consumed the total amount of feed offered. The results of this trial indicate that increasing the

TABLE 7. EFFECT OF ADDING TALLOW TO DIET FOR ENTIRE LACTATION PERIOD ON SOW REPRODUCTIVE PERFORMANCE, TRIAL 3

Level of added tallow	0%	5%	
Digestible energy, kcal/kg	3250.5	3485.1	
Item			SE[a]
No. sows	28	26	
Percentage showing estrus			
≤ 7 d	64.3	57.7	
≤ 12 d	75.0	80.8	
No. sows anestrus	7	5	
Sow performance			
Lact. feed intake, kg/d	3.9	4.1	.2
Daily DE intake, kcal	12,677	14,289	
Sow farrowing wt.[b], kg	170.6	170.7	
Sow weaning wt., kg	156.8	160.8	2.1
Lact. wt. change, kg	-13.8	-9.9	2.1
Postweaning interval, d	6.1	5.9	.4
Farrowing rate[c], %	57.1	61.9	
Subsequent litter size[d]	7.6	8.3	.8
Litter performance			
Survival rate, %	87.1	81.4	2.5
No. weaned[e]	8.3	7.7	.3
Weaning weight, kg	4.9	4.8	.2
Litter weaning wt., kg	40.5	37.0	1.6

[a]Standard error.
[b]Weight of sow ≤ 24 h post farrowing.
[c]Percent of sows cycling which had a subsequent litter.
[d]Number pigs born alive.
[e]Significant (P<.10).

energy intake of the sows following weaning may shorten the weaning-to-breeding interval, although it was not significant (P>.10) with the number of sows used in this trial. Sows receiving the tallow diet appeared to express estrus more quickly than either the control- or cornstarch-fed groups. However, by 12 days after weaning, the sows fed the control diet had equalled those fed tallow in percent showing estrus, with the sows on the cornstarch diet being numerically lower than the sows fed either of the other diets.

Subsequent farrowing rate is numerically, although not significantly, lower for sows fed the control and cornstarch diets than for those fed the tallow diet. The higher energy cornstarch and tallow diets did result in a slight, although nonsignificant, increase in the subsequent litter size over the control diet (7.5 & 7.3 vs 5.8 pigs).

Trial 2. The results of this trial varying the level of tallow in the diet from weaning to breeding are shown in table 9. These sows were weaned and bred in July and August. The July group was made up of primiparous sows, with the August group being 2/3 multiparous and 1/3 primiparous. There were some incidences of feed refusal during the July trial, especially in the 25% tallow treatment (5 of 12 refused some feed at least one day). This feed refusal may have been diet related, but more likely was due to the high environmental temperatures, as the sows in the August group did not show the same pattern of feed refusal.

There was a significant parity influence on the postweaning interval, with the average days to estrus for the multiparous sows being 2.7 days earlier than the primiparous sows (3.7 vs 6.4 d). This is in agreement with Aumaitre et al. (1976), Hurtgen et al. (1980), and Szarek et al. (1981) who found the delay in the onset of estrus to be more obvious in the primiparous sow than in the multiparous sow. When parity is disregarded, the average postweaning interval is found to be significantly shorter for the 25% tallow diet than for the 14% tallow diet, with the control diet statistically similar to both tallow diets.

There were no significant differences showing up between the breeding

TABLE 8. EFFECT OF ENERGY SOURCE IN DIET FROM WEANING TO BREEDING ON SOW REPRODUCTIVE PERFORMANCE, TRIAL 1[a]

Item	Diet			
	Control	Cornstarch	Tallow	SE[b]
No. sows	10	11	12	
Sows weaning wt., kg	142.3[e]	144.5[e,f]	151.4[f]	3.9
Avg. postweaning interval, d	7.5	5.9	5.9	.8
Percentage showing estrus				
$\leq$ 7 d	50.0	54.5	75.0	
$\leq$ 12 d	90.0	63.6	91.7	
No. sows anestrus	1	4	1	
Farrowing rate[c], %	44.4	42.9	63.6	
Subsequent litter size[d]	5.8	7.5	7.3	1.8

[a]Breeding diets fed until estrus detected.

[b]Standard error.

[c]Percent of sows cycling which had a subsequent litter.

[d]Number pigs born alive.

[e,f]Means in the same row with different superscripts differ significantly ($P<.10$).

treatments in the percentage showing estrus for either the multiparous or primiparous sows. The subsequent farrowing rate shows a slight, though nonsignificant advantage for the sows fed the control and 25% tallow diets over those fed the 14% tallow diet. The number of pigs in the subsequent litter was statistically similar among the treatments, with the control treatment having a slight numerical advantage over the 14% and 25% tallow treatments (11.0 vs 9.5 & 8.7 respectively).

Trial 3. The influences of energy source on reproductive performance for both periods of this trial are shown in table 10. In period I, there were 14 multiparous and 16 primiparous sows, with a significant parity difference in days to postweaning estrus in favor of the multiparous sows (4.3 vs 5.7 d) much as was seen in trial 2. However, since there was no interaction between breeding treatment and parity, data were pooled showing similar intervals for the tallow and soybean oil diets, with a slightly longer interval for the control diet (4.8 & 4.9 vs 5.3 d). Percentage of females showing estrus within 7 days postweaning is similar for all treatments, but those fed the tallow- and soybean oil-supplemented diets did tend to be earlier in returning to estrus, with a higher percentage showing heat by 5 days after weaning (80 vs 40 %). Feed treatment from weaning to breeding did not have a significant effect on the farrowing rate; however, the sows fed the soybean oil diet had a larger litter than the other two treatments in the subsequent farrowing.

In Period II, primiparous sows were used following a lactation trial in which one half received 5% tallow for the entire lactation period. These sows followed the same trend of feed refusal as was observed in trial 2. The July group had several (14) incidences of feed refusal, while the August group only had 4. It is interesting to note that while the feed refusals in July were most numerous for the soybean oil diet (8), the control diet was also quite high (5). The control diet was the only diet refused in the August group. There were no significant differences between treatments when looking at the average postweaning interval. By day 7 and 12, there was a slight

TABLE 9. EFFECT OF ENERGY LEVEL IN DIET FROM WEANING TO BREEDING ON SOW REPRODUCTIVE PERFORMANCE, TRIAL 2[a]

Item	Diet			
	Control	14% Tallow	25% Tallow	SE[b]
No. sows	22	24	22	
Sows weaning wt., kg	158.3	161.4	156.8	2.7
Avg. postweaning interval, d	5.04[e,f]	5.2[e]	4.58[f]	.37
Percentage showing estrus				
Multiparous $\leq$ 7d	100	75.0	85.7	
$\leq$ 12d	100	87.5	85.7	
Primiparous $\leq$ 7d	73.3	56.3	73.3	
$\leq$ 12d	80.0	75.0	80.0	
No. sows anestrus	3	5	4	
Farrowing rate[c], %	57.9	36.8	55.6	
Subsequent litter size[d]	11.0	9.5	8.7	1.6

[a]Breeding diets fed until estrus detected.

[b]Standard error.

[c]Percent of sows cycling which had a subsequent litter.

[d]number pigs born alive.

[e,f]Means in the same row with different superscripts differ significantly (P<.10).

TABLE 10. EFFECT OF ENERGY SOURCE IN DIET FROM WEANING TO 30 DAYS POSTBREEDING ON SOW REPRODUCTIVE PERFORMANCE, TRIAL 3

Item	Control	Tallow	SB Oil	SE[a]
Period I[b]				
No. sows	10	10	10	
Sow weaning wt., kg	188.5	190.6	185.3	4.5
Avg. postweaning interval, d	5.3	4.8	4.9	.2
Percentage showing estrus				
$\leq$ 5 d	40.0[g]	80.0[f]	80.0[f]	
$\leq$ 7 d	90.0	100	90.0	
$\leq$ 12 d	90.0	100	90.0	
No. sows anestrus	1	0	1	
Farrowing rate[d], %	66.7	50.0	55.6	
Subsequent litter size[e]	8.7[f,g]	6.7[f]	10.5[g]	1.2
Period II[c]				
No. sows	17	18	19	
Sow weaning wt., kg	169.3	169.3	170.4	3.1
Avg. postweaning interval, d	6.0	6.3	5.8	.5
Percentage showing estrus				
$\leq$ 7 d	64.7	66.7	52.6	
$\leq$ 12 d	70.6	88.9	73.7	
No. sows anestrus	5	2	5	
Farrowing rate[d], %	50.0	50.0	78.6	
Subsequent litter size[e]	6.4[f]	10.6[g]	6.7[f]	1.3

[a]Standard error.

[b]No treatment during lactation; 14 multiparous sows and 16 primiparous sows.

[c]Half the sows received tallow during lactation; all were primiparous sows.

[d]Percent of sows cycling which had a subsequent litter.

[e]Number pigs born alive.

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

numerical advantage for sows fed the tallow diet in percentage showing estrus, but this was not a significant difference. The subsequent farrowing rate tends to favor the sows fed the soybean oil (P=.13), while litter size shows a significant advantage for feeding tallow.

Digestion Trial

Trial 4. The apparent digestibilities of the diets used in this digestion trial are shown in table 11. These results would indicate that some property of the dried animal and vegetable fat (DAV) diet is having a detrimental effect on the nutrient digestibilities when compared to the other diets. The DAV diet consistently shows lower digestibility coefficients for energy, ether extract, and dry matter than do the soybean oil (SO) and dried choice white grease (DCWG) diets.

Rate of passage through the sow's digestive tract (figure 1) was increased (P<.05) with sows fed DAV, offering an explanation to the decreased digestibilities of the various nutrients.

Ether extract digestibility of the control diet was 70.19%. The addition of 8% fat, regardless of the source, increased the digestibility significantly (P<.001). The ether extract digestibility for the control diet may be low due to the greater relative proportion of metabolic fecal fat of those sows. However, the DAV treatment was lower (P<.05) than the SO and DCWG.

Nitrogen digestibility was quite similar for all four treatments, with the SO diet having the highest digestibility and the control diet showing the lowest. However, the sows fed the control diet had a lower (P<.05) nitrogen retention than the three added fat diets. Three of the sows on the control diet actually showed a negative nitrogen balance. This could be partially explained by the low protein content of the control diet (13.1%).

The impact of the energy digestibility is shown in figure 2. Gross energy values

TABLE 11. APPARENT DIGESTIBILITIES AND OTHER PROPERTIES OF DIETS[a] CONTAINING VARIOUS FAT SOURCES, TRIAL 4[b]

Item	CONT	SO	DAV	DCWG	SE[c]
DM digestibility, %	88.34[e]	88.27[e]	83.27[f]	88.14[e]	.29
Energy digestibility, %	88.67[e]	88.47[e]	79.95[f]	88.63[e]	.36
Ether extract digest., %	70.19[g]	92.17[e]	88.10[f]	93.55[e]	1.21
Nitrogen digestibility, %	83.54[f]	85.72[e]	84.85[e,f]	85.47[e,f]	.62
Nitrogen balance, g/d	.76[f]	8.31[e]	8.66[e]	10.11[e]	1.31
Digestible energy, kcal/kg	3755[f]	4066[e]	3749[f]	4142[e]	16
Rate of passage[d], h	50.4[e]	50.4[e]	38.0[f]	53.0[e]	2.9

[a]CONT=control; SO=soybean oil; DAV=dried animal & vegetable fat; DCWG=dried choice white grease.

[b]5-day total collection digestion trial.

[c]Standard error.

[d]Rate of passage measured as time from feeding marker until first appearance in feces.

[e,f,g]Means in the same row with different superscripts differ significantly ($P<.05$).

FIGURE 1
RATE OF PASSAGE

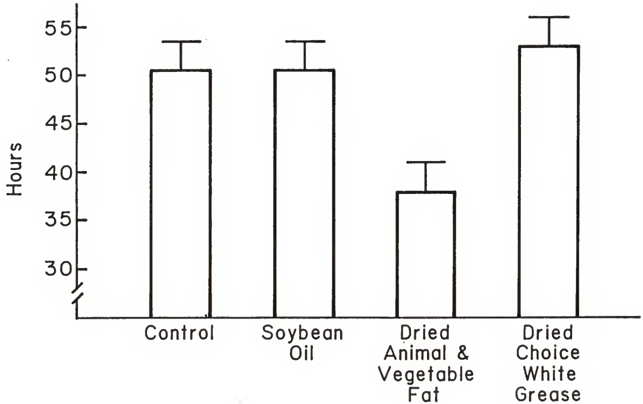
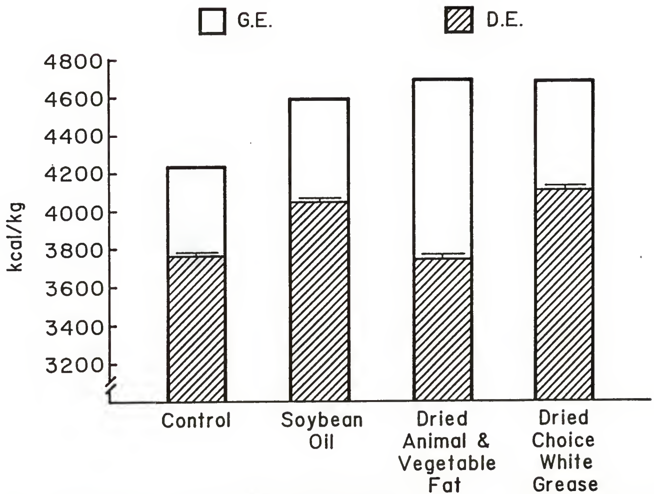


FIGURE 2

ENERGY CONTENT OF FEED



are similar for the two dried fat products. However, when looking at digestible energy, the value for the DAV diet drops dramatically.

The digestible energy values and ether extract digestibilities of the fat sources used in this trial (table 12) were determined by the indirect method of determining digestibility as outlined by Crampton and Harris (1969). The DE values were determined by the following equation:

$$\frac{\text{(DE of diet)-(DE of CONT without C.S.)}}{\text{(\% of tested product in diet)}}$$

Example: $$\frac{(4066.3 - 3430.5)}{8\%} = 7947.5 \text{ kcal/kg}$$

The digestibility of ether extract of the fat sources was determined by the following equation:

$$(100)\ \frac{\text{(g EE retained from test diet) - (g EE retained from basal portion of diet)}}{\text{(g EE provided by test diet) - (g EE provided by basal portion of diet)}}$$

Example: $$(100)\ \frac{(844.03 - 152.27)}{(914.4 - 216.7)} = 99.15\%$$

When using this calculation, it is assumed that the corn starch does not add any ether extract to the control diet.

Fatty acid analysis of the three fat sources used is presented in table 13. As with the young pig and chick, it appears that the fatty acid composition affects the utilization of dietary fat by the sow. In the young pig, Sewell and Miller (1965) report a significant decrease in the absorbability of stearic acid as compared to palmitic, oleic, and linoleic acids. The results of this study are in agreement, in that DAV (which is high in stearic acid) is less digestible than SO or DCWG (which have lower stearic acid concentrations).

Degree of saturation may also be the cause of the reduced digestibilities seen in the DAV treatment. This fat product is processed in such a way as to improve its flowability. In this process of hydrogenation, the fat becomes more saturated and apparently less digestible. The fat product by itself has the texture of a soap, and the

TABLE 12. DIGESTIBILE ENERGY VALUES AND ETHER EXTRACT DIGESTIBILITY OF FAT SOURCES, TRIAL 4

Item	Corn Starch	Soybean Oil	Dr. An. & Veg. Fat	Dr.Ch.White Grease
Digestible energy, kcal/kg	4060	7947.5	3381.5	7118.0
Ether extract digestibility, %	-	99.15	93.14	99.79

TABLE 13. FATTY ACID COMPOSITION OF FATS AND OILS USED IN DIGESTION TRIAL[a]

	%											%	
Fat or oil	10:0	12:0	14:0	16:0	16:1	17:0	17:1	18:0	18:1	18:2	18:3	Sat.	Unsat.
Soybean oil[b]			.5	14.3	.5			1.6	27.4	45.5	10.2	16.4	83.6
Dried animal & vegetable fat	<1.0	.14	2.41	23.57	1.35	.99	.22	47.53	13.96	7.20	2.58	74.7	25.3
Dried choice white grease			1.0	26.0				11.5	58.0	3.5		38.5	61.5

[a]No. of C atoms:no. of double bonds.

[b]Edwards (1964).

feces had the consistency of a very sticky clay. When the feces were dried, specks of the fat could be observed throughout.

Chain length does not appear to play a role in the utilization of fats by the sow. In the present study, DCWG and DAV have similar concentrations of long and short chain fatty acids, but the digestibilities are quite different (table 11). This contrasts with work done by Eusebio et al. (1965) and Lawrence and Maxwell (1983) which show that those fats having a shorter average chain length appear to be more readily digested.

Summary

Three feeding trials utilizing 185 sows (149 primiparous and 36 multiparous) and a digestion trial were conducted to evaluate the effects of feeding various levels and sources of supplemental energy during lactation and from weaning to rebreeding on reproductive performance and nutrient digestibility.

Sows fed tallow (5% or 10%) during lactation had similar reproductive performances as sows fed the basal milo-soybean meal diet. Ad libitum feed intake was not affected by the addition of tallow for either the last week of lactation or for the entire three week lactation. However, daily DE intake was increased with the addition of tallow to the diets. Lactation weight change appeared to be influenced more by the total litter weight weaned than by the energy intake of the sow. Survival rate of the pigs was not influenced by adding tallow during the lactation period.

The addition of cornstarch (CS) or tallow (TAL) in the breeding diet did not result in any significant increases in reproductive performance however, the sows on the higher energy diets (CS and TAL) did tend to show estrus earlier (5.9 vs 7.5 d) than those sows on the basal diet. Adding 25% tallow to the breeding diet did not influence the average days to estrus when compared to the basal diet, but did decrease the days to estrus when compared to the diet containing 14% tallow ($P<.10$) in trial 2.

Sows fed diets with 10% tallow (TAL) or 10% soybean oil (SO) added tended to show estrus earlier than those consuming the basal diet in Period I of trial 3. The percentage showing estrus by 5 days postweaning was 80% for TAL and SO compared to 40% for the control treatment. This difference was lost by 7 days postweaning, and was not observed in Period II of the trial.

In the digestion trial, two diets containing 8% dried fat (dried animal and vegetable fat (DAV) and dried choice white grease (DCWG)) were compared to a diet

containing 8% soybean oil (SO) and a control diet containing 8% corn starch (CONT). The digestion coefficients for energy, ether extract, and dry matter were lower for the DAV diet than for the SO, DCWG, or CONT diets. Nitrogen digestibility and nitrogen retention were lowest for the CONT diet, possibly because of its low protein content (13.1%). Rate of passage through the digestive tract was faster ($P<.05$) for the DAV diet than for the other three diets tested. These results suggest that dry fat sources evaluated were markedly different in nutritional value. The calculated DE values (kcal/kg DM) were 3382 for the DAV, and 7118 for the DCWG.

Subsequent litter size, measured as number of pigs born alive, tended to be quite variable. In trial 1, the sows on the CS and TAL diets showed a slight increase over the sows on the control diet. In trial 2, all three treatments were similar, with the sows on the control diet having a slight advantage over the sows on both tallow diets. The sows fed the tallow diet from weaning until 30 days postbreeding in trial 3 showed an increase ($P<.05$) in litter size compared to those fed the SO or control diets.

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EFFECTS OF SOURCE AND LEVEL OF SUPPLEMENTAL ENERGY ON REPRODUCTIVE PERFORMANCE OF SOWS

by

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Abstract

Two lactation trials using a total of 87 sows were conducted to evaluate the effect of adding tallow to the lactation diet on sow and pig performance. Three trials using 185 sows were conducted to evaluate the effect of adding cornstarch, tallow, and soybean oil to the diet from weaning to breeding. A fourth trial was conducted using 12 sows to determine the apparent digestibilities of various fat products by the sow.

Sows fed tallow (5% or 10%) during lactation had similar reproductive performances as sows fed the basal milo-soybean meal diet. Ad libitum feed intake was not affected by the addition of tallow for either the last 7 days of lactation (10% tallow) or for the entire three week lactation (5% tallow). However, DE intake was increased with the added fat. Survival rate of the pigs was not influenced by adding tallow during the lactation period. The addition of tallow during the lactation period did not influence the average days to estrus postweaning.

In trial 1, the addition of cornstarch (CS) or tallow (TAL) in the diet from weaning to breeding did not significantly influence reproductive performance, however, sows fed the higher energy diets (CS and TAL) did tend to return to estrus earlier (5.9 vs 7.5 d) than those sows on the basal diet. In trial 2, the addition of 25% tallow to the breeding diet from weaning to breeding decreased the average days to estrus ($P<.10$) when compared to the diet containing 14% tallow. However, the basal diet did not differ significantly from either tallow diet.

In trial 3, the test diets were fed from weaning to 30 days postbreeding. Sows fed diets containing 10% tallow (TAL) or 10% soybean oil (SO) tended to exhibit estrus quicker than those consuming the basal diet in Period I. The percentage of sows showing estrus by 5 days postweaning was 80% for the TAL and SO treatments compare to 40% for the control treatment. This difference was lost by 7 days, and was not

observed in Period II of the trial.

Subsequent litter size varied among the treatments for each trial. Diet fed from weaning to breeding did not appear to affect litter size except in trial 3 where the sows fed the tallow diet had larger litters ($P<.05$).

In the digestion trial, twelve sows were used to determine the apparent nutrient digestibility of three fat sources. Fat sources evaluated were soybean oil (SO), an 85% dry animal and vegetable fat (DAV), and an 80% dry fat product made with choice white grease (DCWG). The control diet was a 13.1% crude protein corn-soybean meal diet with 8% cornstarch. Fat sources were added to the control diet to supply 8% added fat. The sows were used in a crossover design, with three sows per diet in each of two periods. Each period consisted of a 5 day adjustment and a 5 day total collection of urine and feces. Sows were fed 2 kg daily. Digestibility of dry matter, energy, and ether extract were higher ($P<.05$) for SO and DCWG than for DAV, suggesting that dry fat sources vary in energy and fat digestibility. Rate of passage through the digestive tract was faster ($P<.05$) for DAV than for the other diets.