

(EFFECT OF DIETARY LYSINE AND ENERGY INTAKE DURING LACTATION
ON SOW AND LITTER PERFORMANCE
THROUGH THE FIRST AND SECOND PARITIES /

by

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I would like to dedicate this manuscript to my wife Rachel, my son Kyle and my daughter Karma. Without their love, patience, understanding and support this would never have been completed.

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ABSTRACT

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INTRODUCTION

Pork producers face increased competition with many other facets of agriculture for a share of consumers dollars. In order to compete and still emphasize profitability, swine operations must be finely tuned and run at optimum efficiency. While all phases of production must be run efficiently, sow reproductive performance has the most impact upon production efficiency and ultimately profitability in swine operations. Sow reproductive performance can be improved with increases in conception rate, ovulation rate, pig survivability, or a reduction in farrowing interval.

Modern swine units must operate near full capacity in order to be highly efficient. Lactation length and weaning to first estrus intervals must be shortened to accommodate continuous farrowing. With more pressure on sow reproductive efficiency and the desire to run units at full capacity stricter, culling practices are utilized. The result is more primiparous sows are in the breeding herd. Unfortunately, primiparous sows show increased intervals from weaning to estrus compared to multiparous sows. Research has shown low intakes of either energy and/or protein result in loss of weight and backfat, and consequently increased weaning to first estrus intervals.

In recent years research has made great strides in understanding what levels of protein or energy are essential for optimum reproductive performance. It is still not clear as to which is more important protein or energy, or which combination of protein and energy gives optimum sow reproductive performance. This will be the focus of future research as the quest continues to solve the problem of maximizing sow production and decreasing the weaning to estrus interval.

Review of Literature

Effect of Feed Intake During Lactation on Sow and Litter Performance

Feed intake is influenced by parity of sow, season of year (temperature and photoperiod) and composition of the diet (Britt, 1986). High levels of daily feed intake during lactation minimize sow lactation weight loss. Elsley et al. (1969), Libal and Walstrom (1975), King and Williams (1984a), showed lactation weight loss to be dependent upon lactational feed intake. Elsley et al. (1969), Libal and Walstrom (1975) and King and Williams (1984a) found sows that which gain more weight during gestation will lose more weight during lactation, regardless of lactation feed intake. However, total

weight loss is reduced with high lactation feed intakes (Elsley et al., 1969).

Sow feeding level during lactation does not affect ovulation rate, pig survivability, or embryo survivability (King and Williams, 1984a). Elsley et al. (1969) found only slight increases in litter weight due to increased feed intake, however pigs were creep fed and this may have masked the differences in milk production. Reese et al. (1982a) saw higher weaning weights with higher sow feed intakes when no creep feed was offered to pigs.

Sow lactation feed intake influences the days from weaning to estrus. King and Williams (1984a) found that primiparous sows fed ad libitum during lactation returned to estrus quicker than those that were limit fed during lactation. In primiparous sows, daily feed intakes below 4.5 kg/d result in a delayed return to estrus (King and Williams, 1984a; King and Dunkin, 1986a). Many times ad libitum feeding during the first parity resulted in a feed intake of less than 4.5 kg/d (Cox et al., 1983; King and Williams, 1984b). In contrast, Armstrong et al. (1986) found no differences in reproductive performance when comparing ad libitum fed sows (3.9 kg/d) to limit fed sows (2.6 kg/d) during lactation, however the small number of sows used and the low daily feed intakes on the ad libitum fed sows may account for the differing results.

Effect of Energy Intake During Lactation
on Sow and Litter Performance

A major thrust of research in recent years has been to look at different methods of increasing dietary energy intake in lactating sows, in hopes of shortening the weaning to estrus interval. It has been well documented that sow lactation weight loss is highly dependent upon energy intake during lactation (Elsley et al., 1968; O'Grady et al., 1975; Reese et al., 1982a,b; 1984; Nelssen et al., 1985a; Armstrong et al., 1986; King and Dunkin, 1986a,b). Nelssen et al. (1985b) showed a linear ($P < .05$) decrease in both backfat and weight loss as energy intake was increased from 10 to 12 to 14 Mcal ME/d during lactation. This is in agreement with the recent findings of Brendemuhl et al. (1989) which show that low energy intake during lactation resulted in increased backfat loss. The National Research Council (1988) recommends 17.5 Mcal ME/d for both primiparous and multiparous sows. Noblet and Etienne (1987) calculated the energy requirement of a 160 kg sow producing 8 to 9 kg milk per day to be 17.5 Mcal ME/d to meet maintenance and production needs. Since most primiparous sows are unable to consume adequate energy intake, weight loss during lactation is often considered normal.

Amino acids are used as energy sources during periods of energy deficiency (Duee and Desmoulin, 1982; Reese et al.,

1982a; Nelssen et al., 1985a). Amino acid utilization for energy results in deamination and urea synthesis, which results in increased serum urea concentrations. Serum urea concentrations are used as an index of amino acid degradation. Amino acids can be catabolized from either dietary or endogenous protein, or a combination. Serum creatinine concentration is used as an index of muscle catabolism (Wallach, 1978). Nelssen et al. (1985b) observed an increase across all dietary treatments in serum urea concentrations at d 14 of lactation compared to d 110 of gestation levels. However, by d 28 of lactation serum urea concentrations had decreased from d 14 levels. A linear decrease in serum urea concentration was also observed as energy level increased from 10 to 14 Mcal ME/d at d 14 and d 28 of lactation (Nelssen et al., 1985b). In this same experiment, serum creatinine concentrations were numerically lower for sows fed the 14 Mcal ME/d diet during lactation, indicating a trend of lowered muscle catabolism at the higher energy intake.

Energy restriction during lactation results in a delayed return to estrus in primiparous sows (Reese et al., 1982a,b; Cox et al., 1983; King and Williams, 1984b). Reese et al. (1982a,b) found that the interval from weaning to estrus was delayed when energy intakes were at 8 Mcal ME/d during lactation. Cox et al. (1983) showed an increase in days to return to first estrus when sows consumed 9.6 Mcal ME/d.

King and Williams (1984b) found a delay in sows returning to estrus in primiparous sows when energy intake was less than 6.3 Mcal ME/d. Nelssen et al. (1984b) saw no differences in days from weaning to first estrus of primiparous sows when the lowest daily energy intake was 10 Mcal ME/d, however sows receiving 10 Mcal ME/d were numerically slower to return to estrus than those receiving 12 and 14 Mcal ME/d. O'Grady et al. (1973) found no effect on days to first estrus when sows received at least 12 Mcal ME/d. In contrast, Armstrong et al. (1986) and Brendemuhl et al. (1987) found no energy intake effect on days to first estrus postweaning when energy intake was 8 Mcal ME/d. From these findings it is apparent that sow energy intake does affect the weaning to estrus interval, but the exact lactational energy intake at which delayed estrus will occur hasn't been established.

It would appear that 8 to 10 Mcal ME/d energy intake is the minimum energy intake required by lactating sows, as below 8 Mcal ME/d there is a delayed return to estrus (Reese et al., 1982a,b; Cox et al., 1983). Lactational energy intakes above 10 Mcal ME/d appear to reduce the chances of sows failing to return to estrus postweaning.

The effects of sow lactational energy intake on pig weaning weight and litter weaning weight are variable due to creep feeding of litters in some studies and not in others. Experiments in which creep feed was provided and weaning age

was at least 28 d found inconsistent or no effect on pig performance due to sow energy intake (Elsley et al., 1968; O'Grady et al., 1973; Reese et al., 1982a; 1984). In research trials where no creep feed was offered and pigs were weaned at 28 d or less, sow energy intakes of less than 10 Mcal ME/d resulted in reduced pig and litter weaning weights (Reese et al., 1982b; Nelssen et al., 1985b; Duloher, 1987). In contrast, Brendemuhl et al. (1987, 1989) saw reduced pig weights, but no effect on weaning litter weights when energy intake was at 8 Mcal ME/d compared to energy intakes of 16 Mcal ME/d.

Reproductive performance was thought to be highly correlated to sow lactational energy intake for many years, however research by Elsley et al. (1968); O'Grady et al. (1973); Reese et al. (1982b) and King and Williams (1984b) found sow energy intake to have no effect on ovulation rate, subsequent litter size, embryo mortality or gestation weight change. In contrast, Kirkwood et al. (1988) found sows with higher energy intakes during lactation farrowed larger litters at the second and subsequent farrowings. O'Grady et al. (1973) did show reduced milk yield in second and third parities when sow energy intake was restricted to 12 Mcal ME/d during a six week lactation.

Gestation weight gain was not affected by energy intake during lactation (Elsley et al., 1968; Adam and Shearer, 1975;

O'Grady et al., 1975). Sows with low energy intakes during lactation deposited more fat during gestation and farrowed lighter weight pigs, even though there was no effect on sow weight gain during lactation, number of pigs farrowed or weaning litter weight in subsequent lactations (Elsley et al., 1968; O'Grady et al., 1973; Reese et al., 1982b).

Effect of Energy Source on Sow and Litter Performance

There has been considerable debate over whether a calorie is a calorie to a sow in regard to the energy source, especially with the advocacy of high energy diets during lactation. Supplementation of fat offers an excellent pathway to increase dietary energy intake during lactation, but there appears to be little or no effect of energy source during lactation on sow and litter performance.

Boyd et al. (1978b) compared tallow and corn starch diets fed the last ten days of gestation and during lactation to provide 9300 kcal/d. They found an increase in colostrum fat content due to the addition of tallow the last ten days of gestation. This is in agreement with the similar findings of Coffey et al. (1982) in which diets supplemented with fat had higher milk lipid content than diets supplemented with high fructose corn syrup at 24 h postfarrowing. Milk fat

content didn't remain higher for the entire lactation period (Boyd et al., 1978b) and consequently sows on the corn starch diets actually had slightly higher pig survival rates than the sows receiving the tallow supplemented diets. In contrast, Coffey et al. (1982) found milk lipid content to be higher throughout the lactation period when tallow and corn starch supplemented diets were fed during late gestation and for the entire lactation, however there was no difference in number of pigs born alive, litter weaning weight or survival rate.

Nelssen et al. (1985a) compared tallow and corn starch supplementation to sow diets during late gestation and during lactation, and found energy source had no effect on pig weaning weights, weaning litter weights or the number of days to first estrus postweaning. Seerley et al. (1981) compared corn oil and animal fat, and found no differences in feed intake, sow weight loss or litter weaning weights. Nelssen et al. (1985a) found serum urea concentrations to be higher at d 14 and d 28 of lactation on the tallow added diets compared to the corn starch supplemented diets, apparently as the result of higher amino acid catabolism. Sow weight loss during lactation was also higher for sows fed the tallow added diets compared to the corn starch supplemented diets. Nelssen et al. (1985a) also found tallow supplemented diets were less digestible. Reduced digestibility of tallow was thought to be

caused by the short adjustment period of tallow being fed only six days prior to farrowing.

Effect of Feeding Supplemental Fat During Late Gestation on Sow and Litter Performance

Baby pig death losses are highest in the first three days after birth (Hartsock et al., 1977). This high rate of mortality in most herds can be attributed more to nutritional deficiencies rather than crushing as previously thought (Edwards, 1972). Thus, increasing available energy to the newborn pig appears to be the best method of combatting this problem. Research has shown feeding of supplemental fat during late lactation increases the colostral and milk fat concentration (Okai et al., 1977; Boyd et al., 1978b; 1979; Pettigrew, 1978; 1981). Feeding fat to sows results in more energy being available to the neonatal pig and 4.1% higher survival rates if pig survival rate was below 80% (Pettigrew, 1981). Small pigs at birth show the greatest benefit to fat supplementation of late gestation diets sow diets. Moser et al. (1978) found that feeding fat to sows in late gestation improved survivability of pigs weighing less than 1.0 or 1.1 kg at birth by 17.1%. Britt et al. (1986) were in agreement showing a 10% increase in survivability of pigs weighing less

than 1.1 kg when sows received fat supplementation during late gestation.

Supplemental feeding of fat during late gestation resulted in more pigs per litter, but no effect on either pig weights or litter weights (Pettigrew, 1981). In conclusion feeding fat to sows in late gestation is beneficial when pig survivability rate for the sow herd is below 80%.

Effect of Feeding Supplemental Fat During Lactation on Sow and Litter Performance

There has been considerable interest in fat supplementation throughout lactation. Fat addition in late gestation has resulted in increased milk fat content and pig survivability and the desire to increase lactational energy intake is evident. Results from experiments in which supplemental fat has been fed during lactation have been highly variable, with some showing no reduction in feed intake due to the feeding of fat supplemented diets (Seerley et al., 1981; Cox et al., 1983; Shurson et al., 1986). Supplementation of fat during lactation has resulted in increased caloric intake (Stahly et al., 1980). In contrast, other experiments (Boyd et al., 1978; 1980; Pollman et al., 1980; McGlone et al., 1988) showed a decrease in daily feed intake when fat supplemented diets were fed during lactation.

In several experiments addition of fat to sow lactation diets were more beneficial in summer than during the winter, resulting in reduced days from weaning to estrus in summer (Allee and Salva, 1978; Cox et al., 1983). Cox et al. (1983) found sow weight loss was not affected by fat supplementation in summer, however sows receiving the fat supplemented diets in winter lost more weight. In addition, fat supplementation in summer decreased the number of days to return to estrus in summer. However, feeding fat supplemented diets during lactation in winter tended to increase the days required to return to estrus (Cox et al., 1983). In contrast, other research has shown no seasonal differences in feeding supplemental fat during lactation (Pettigrew, 1978; Seerley et al., 1981; Shurson et al., 1986).

Milk yield and milk fat content is increased by feeding supplemental fat during lactation (Kruse et al., 1977; Pettigrew, 1978; Boyd et al., 1982; Lellis and Speer, 1983; Shurson et al., 1986). This increased milk yield has resulted in increased pig and litter weaning weights in some experiments (Boyd et al., 1981; Cieslak et al., 1983; Lellis and Speer, 1983; Shurson et al., 1986). However, Seerley et al. (1981), Cox et al. (1983), and McGlone et al. (1988) found no improvement in litter weaning weight due to fat supplementation. Overall most responses for sow and litter performance to fat supplementation during lactation have been

slightly beneficial for pig weights, litter weaning weights, days to return to estrus and sow lactation weight loss, but not significantly better than lactation diets without added fat (Pettigrew, 1981).

Effect of Protein Intake During Lactation on Sow and Litter Performance

Protein intake is vitally important in keeping lactating sows producing at high levels and returning to estrus quickly after weaning. Low intakes of dietary protein or energy during lactation have long been associated with the problem of an increased interval from weaning to estrus (O'Grady and Hanrahan, 1975; Walker et al., 1979; King and Williams, 1984b; Brendemuhl et al., 1987), especially in primiparous sows. Recent experiments have found that perhaps protein intake during lactation is more vital than energy intake (King and Dunkin, 1986b; Brendemuhl et al., 1987; 1989). King and Dunkin (1986a) found that as long as energy intake was 10 Mcal ME/d, further decreases in weaning to estrus interval were due to increased protein intake.

The effect of gestational dietary protein intake must first be discussed. In order to come up with protein intakes for lactation diets that will maximize production and decrease weaning to estrus interval. When no supplemental protein was

provided during gestation to a corn diet (9% CP), a lactational insufficiency resulted even when lactation diets contained 15 to 16% crude protein (Pond et al., 1968; Baker et al., 1970a,b; Hawton and Meade, 1971). In agreement, Mahan and Mangan (1975) suggest that there is a protein intake carry over from gestation to lactation. Mahan (1977) found in a long term study that sows receiving a protein deficient diet (8.5% crude protein) during gestation and a 20% crude protein diet during lactation still had reduced milk output, reduced pig survivability and reduced progeny gain in the third parity when compared to sows receiving diets containing 14% crude protein during gestation and 15% during lactation.

Mahan and Grifo (1975) fed a vitamin and mineral fortified corn diet (8.2% CP) during gestation and fed lactation diets containing 12, 14, 16, 18 or 20% crude protein, this resulted in a linear ($P < .05$) increase in pig weight and sow feed intake. Also, increasing dietary protein resulted in a linear ($P < .02$) decrease in sow lactation weight loss. In a similar experiments, NCR-42 (1978) used gestation diets of 9 or 15% CP and lactation diets of 12, 16 or 20% CP. This study found sows receiving the 9% CP gestation diets farrowed fewer pigs and had a more pronounced response to the higher lactation CP levels. However, sows on the 15% CP gestation diet showed no benefit to increasing lactation dietary CP above 12%. Shields et al. (1985) fed sows either

5 or 14% CP during gestation and lactation diets containing 5, 14, or 23% CP. Sows fed the 14% CP gestation diet gained more weight during gestation, farrowed heavier pigs, weaned heavier pigs, heavier litters, lost more weight during lactation and had a higher pig survival rate. Sows fed the 5% CP gestation actually gained weight during lactation when fed a diet containing 14 or 23% CP during lactation. Sows fed protein deficient diets during gestation have lowered body protein reserves, lowered ($P < .05$) milk production and reduced pig performance. Feeding low protein diets during gestation can be partially overcome by feeding high CP levels during lactation (Mahan and Grifo, 1975; Shields et al., 1985). Over three parities, sows were not able to compensate for low protein intakes during gestation with higher lactation protein intakes, as protein reserves were so low that sows required hormone therapy to prevent neonatal pig starvation (Mahan, 1977).

In order to maintain optimal reproductive performance sow gestation diets must contain 14 to 15% CP (Mahan, 1977; NCR-42, 1978). Low intake of crude protein during lactation ($< 500\text{g/d}$) results in increased days from weaning to first estrus, decreased pig weights, decreased litter weaning weights, increased sow backfat loss during last two weeks of lactation and more total weight loss (O'Grady and Hanrahan,

1975; Walker et al., 1979; King and Williams, 1984b; Brendemuhl et al., 1987).

Serum urea concentrations are an indicator of amino acid catabolism (Duee and Desmoulin, 1982; Reese et al., 1982a; Nelssen et al., 1982). Serum urea concentrations increase as lactation progresses, however serum urea nitrogen concentrations were higher in sows receiving the high protein diets than in sows receiving the low protein diets as a result of more amino acid catabolism (Brendemuhl et al., 1987). Brendemuhl et al. (1989) found backfat loss to be more dependent on energy intake than protein intake, as sows on low protein diets catabolized more protein from skeletal muscle and internal organs than sows on high protein diets. Energy restriction resulted in more fat loss from adipose tissue and internal organs instead of muscle catabolism (Brendemuhl et al., 1989). In agreement, King and Williams (1984b) and Brendemuhl et al. (1987) found sows receiving lactation diets of high energy-low protein and low energy-high protein had similar weight losses but differing backfat losses. Protein levels above 16% crude protein in either gestation or lactation resulted in no improvement in sow or litter performance (NCR-42, 1978).

Wilkinson et al. (1982) used urinary nitrogen levels and plasma lysine concentrations to determine that Landrace X Large White sows nursing ten pigs per litter had total lysine

requirements of 48.5 to 51 g/d. This is far above the NRC (1988) recommendations, however other work does not substantiate improved sow and litter performance with lysine intakes above 32 g/d (NCR-42, 1978; King and Williams, 1984a, b; King and Dunkin, 1986a).

Effect of Energy and Protein Intake During Lactation on Sow and Litter Performance

Previous work has shown that a deficiency in lactation energy intake (Reese et al., 1982a,b; King and Williams, 1984b; Nelssen et al., 1985b) or protein intake (O'Grady and Hanrahan, 1975; Walker et al., 1979; King and Williams, 1984b; Brendemuhl et al., 1987) resulted in increased sow weight loss, reduced pig weights and an increased interval from weaning to estrus. Recent sow experiments focusing on both energy and protein by King and Williams (1984a,b) and King and Dunkin (1986b) have shown that incidence of postweaning anestrus will be reduced among first litter sows if their daily lactation diets contain 14 Mcal of metabolizable energy, 700 g CP and 31 g lysine. However, in a recent experiment King and Dunkin (1986b) saw no improvement in sow performance due to increases in energy intake above 10 Mcal ME/d. This agrees with work by Brendemuhl et al. (1987) in which sows failed to respond to lactational energy intakes above 8 Mcal ME/d.

However, this data is in contrast to other research that showed declines in sow performance when energy intake was below 8 Mcal ME/d (Reese et al., 1982a,b) or below 9.6 Mcal ME/d (Cox et al., 1983). Part of this difference may be explained by the higher protein levels in some experiments as Brendemuhl et al. (1987) used crude protein intakes of 760 g/d which is well above the NRC, (1988) recommendations of 690 g/d CP. This excess protein is most likely being catabolized by the sow and used for energy. It appears more research needs to be done with energy levels at or above 10 Mcal ME/d and dietary crude protein content between 13 and 16% to determine if such high levels of crude protein are beneficial when both energy and crude protein levels in the diet are adequate.

Amino Acid Requirements of the Lactating Sow

In the past swine producers have relied heavily upon corn-soybean meal diets and formulated diets on a crude protein basis. In recent years more interest has been shown for alternative protein sources, which may require addition of synthetic amino acids in order to meet the requirement of indispensable amino acids. Requirements for indispensable amino acids were calculated by Baker et al. (1970) using the maintenance requirements of the nonpregnant gilt, then adding

the amounts of amino acids produced in sows milk and dividing by an amino acid digestibility coefficient.

The plasma amino acid curve is the relationship between the intake of a specific amino acid and the concentration of that amino acid in blood plasma. Consequently, the plasma amino acid curve is frequently used to show the relationship between the intake of a specific amino acid and the level of that amino acid in plasma. By using this method, there is no confounding effects with milk secretion as in nitrogen balance measurements (Ganguli et al., 1971). Plasma urea concentrations fall as the most limiting dietary amino acid is increased, while plasma concentrations of the limiting amino acid increase with increasing concentrations in the diet (Lewis and Speer, 1974b).

Lysine is the first limiting amino acid in grain-soybean diets. Lewis and Speer (1973) used nitrogen retention, pig gain, milk production and serum lysine concentration to determine the lysine requirement for the lactating sow, and concluded that .55% lysine was required for optimum lactation performance. In a similar experiment using the plasma amino acid curve, Lewis and Speer (1974b) used five dietary levels of lysine and concluded that .5% lysine was required in a sow lactation diet. Postprandial plasma concentrations were more responsive to amino acid intake than were fasting plasma concentrations (Lewis and Speer, 1974b). Based on this

research, the NRC (1988) estimated the lysine requirement of the lactating sow to be .6%.

Wilkinson et al. (1982) and Schoenherr (1988) through calculations based on maintenance and milk production question whether the NRC (1988) recommendations are adequate for high producing sows. Schoenherr (1988) has calculated that sows nursing 8.5 pigs require 42 g lysine/d to meet her daily lysine requirement. Wilkenson et al. (1982) calculated that Landrace X Large White sows raising ten pigs must consume over 50 g lysine/d to meet her requirements. Presently, there is no data available to evaluate the effects of these high daily lysine intakes on sow and pig performance.

Tryptophan is typically the second most limiting amino acid for corn-soybean meal diets. In a second experiment, Lewis and Speer (1974b) used five levels of tryptophan and the plasma urea curve to determine that a level between .061 and .091% tryptophan is needed for lactating sows. Lewis and Speer (1974a) used a similar experiment with 5 levels of tryptophan to determine the requirement to be .091% for the lactating sow using nitrogen retention, milk production, pig weight gain and plasma amino acid and urea concentrations. This falls just below the range .12 to .16% tryptophan calculated to be the requirement for a lactating sow (Reid, 1961; Baker et al., 1970; Speer, 1971). The NRC (1988) recommendation for tryptophan is .12%.

Threonine is usually the third most limiting amino acid in a grain-soybean meal diets. A series of experiments by Lewis and Speer (1975) determined that the threonine requirements for lactating sows is .42%. This falls in the range of the values calculated as the threonine requirement for the lactating sow by several authors (Reid, 1961; Baker et al., 1970; Speer, 1971) and is similar to the NRC (1988) suggested requirement of .43%.

Isoleucine is usually the fourth most limiting amino acid in corn-soybean meal diets. An experiment was conducted by Haught and Speer (1977) to determine the isoleucine requirement of the lactating sow. Haught and Speer (1977) used milk yield, pig weight gain, nitrogen retention, plasma isoleucine and plasma urea to estimate the lactating sows requirement at .37%. This is very close to the NRC (1988) requirement of .39%. These experiments further establish the accuracy of calculated requirements by Baker et al. (1970) and the reliability of their use by NRC (1988).

Effect of Season, Diet and Environmental Modification
on Sow and Litter Performance

Summer time reduction in sow and litter performance is a perennial problem in the commercial swine industry (Cox et al., 1983). Typically heat stress accounts for much of the depressed feed intake and reduced pig weight gains commonly seen in summer (Stansbury et al., 1988). McGlone et al. (1988) found that heat stress reduced sow feed intake, pig mortality, pig weaning weight and increased sow lactation weight loss. Schoenherr et al. (1989) determined that thermal heat stress is aggravated by high fiber diets and minimized by dietary fat addition. Summer heat stress will usually increase the weaning to estrus interval by as many as 10 d or longer in primiparous sows compared to other seasons (Aumaitre et al., 1976; Fahmy et al., 1979; Hurtgen et al., 1980).

With summer heat stress being a problem in most areas where swine are produced, many management techniques have been used to reduce heat stress in pigs. One of the problems with any environmental modification is that baby pigs require a warm, dry environment. However, the sow is more comfortable, has increased feed intake and crushes fewer pigs when the ambient temperature is 5 to 10° C cooler than needed for pigs (Stansbury et al., 1987). Drip cooling on plastic coated expanded metal floors increased sow feed intake, decreased sow

weight loss, increased pig weights and litter weaning weights, but didn't affect the weaning to estrus interval (McGlone et al., 1988). Sows that were snout cooled during heat stress had increased feed intake and reduced lactation weight loss (McGlone et al., 1988). Snout coolers were more effective on concrete floors than drip cooling, but were not as effective as drip cooling in increasing litter performance, especially on plastic coated flooring (Stansbury et al., 1987; McGlone et al., 1988).

Diet modification by adding supplemental fat during lactation when no other environmental modification is used has been shown to reduce the weaning to estrus interval in summer (Cox et al., 1983; Britt, 1986). Other authors Shurson et al. (1986) and McGlone et al. (1988) did not find any decrease in weaning to estrus interval when high fat lactation diets were fed to lactating sows during summer. McGlone et al. (1988) found a slight increase in weaning to estrus interval when fat was fed in combination with drip cooling in summer.

Drip cooling on plastic coated expanded metal flooring appears to be the most economical and effective method of moderating the environment in summer. Sow and pig performance will be nearly equal to that of the other seasons of the year when sows are drip cooled (McGlone et al., 1988).

Summary

Energy intakes for lactating sows must be at least 8 to 10 Mcal ME/d to prevent delays in return to first estrus. Pig performance appears to be higher when sow lactation energy intakes are at least 12 Mcal ME/d. Fat supplementation is most beneficial when fed in late gestation at 5 to 10% of the diet, especially if herd pig survivability is less than 80%. Adding fat to lactation diets is beneficial in increasing sow energy intake, when drip or snout coolers are not utilized. Fat addition to lactation diets has had little effect on sow and litter performance, except in summer months.

Protein intakes of at least 690 g/d are required by sows during lactation. Gestating sows require diets containing 13 to 14% CP. Low protein intakes during gestation resulted in smaller pigs at birth, reduced milk production, reduced litter weaning weight and delays in return to first estrus. When adequate gestation diets are fed (13-14% CP), lactation diets containing 12 to 14% CP are adequate during lactation. Although some research would indicate Landrace-cross sows have higher requirements for dietary protein, little data is available to support this concept. Lysine intakes of 31 to 34 g/d are required by lactating sows.

Deficiencies of either protein or energy in sow lactation diets increase sow weight loss and reduce pig performance as well as increase the interval from weaning to

first estrus. Increasing dietary protein appears to offer more potential for increasing litter performance and reducing the weaning to estrus interval than attempting to increase energy intake. Increased dietary protein intake during lactation is most beneficial for improving pig performance in 4 to 5 wk lactations.

Drip cooling is the most effective method of reducing heat stress on plastic coated flooring. Drip cooling has resulted in increased sow feed intakes, reduced sow weight loss and reduced backfat loss, plus pig performance is improved. When drip cooling and fat addition are used in combination, the drip cooling eliminates any reduction in weaning to estrus interval that may have resulted from addition of fat alone to sow lactation diets in summer.

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EFFECT OF DIETARY LYSINE AND ENERGY INTAKE DURING LACTATION
ON SOW AND LITTER PERFORMANCE
THROUGH THE FIRST AND SECOND PARITIES

ABSTRACT

The effect of lysine and/or energy intakes on sow and litter performance during a 21 d lactation were examined through two parities. A 2 X 2 factorial design with four replications per parity was used. Dietary treatments consisted of two dietary lysine levels (.65 or .75%) and two soybean oil levels (0 or 3%). One hundred fifty-eight primiparous sows were utilized in parity one. Eighty-seven sows completed both parities. All females received 1.8 kg/d of a 14% CP diet during gestation and were fed the same lactation diet in both parity one and two. There was no lysine X soybean oil interaction for any of the criteria measured in either parity one ($P>.24$) or parity two ($P>.07$). Also, no diet by season interaction for any criteria measured occurred in either parity one or two ($P>.18$). In parity one there was no effect of dietary lysine or soybean oil on sow weight loss, sow backfat loss, pig survivability, weaning litter size, weaning litter weight, average pig weaning weight or percentage of sows returning to estrus by d 7 postweaning. Also, there was no effect of dietary lysine or soybean oil on serum concentrations of urea, creatinine or free fatty acids. Feed intake was depressed ($P<.05$) for sows receiving 3% soybean oil, however caloric intake was not affected by dietary soybean oil addition. Dietary lysine intake had no effect on daily feed intake or percentage of sows returning to estrus by d 14. However, fewer

sows on the .75% lysine diet had returned to estrus by d 28 postweaning ($P<.08$). Addition of 3% soybean oil resulted in fewer sows returning to estrus by d 14 and d 28 following weaning ($P<.03$). In parity two, there was no effect on sow or litter performance of either dietary lysine level or addition of 3% soybean oil, with the exception that sows receiving 3% soybean oil had a longer interval from weaning to estrus ($P<.05$). Based on the results of our experiment, we conclude that for a 21 d lactation a .65% lysine diet without added fat is adequate for sow and litter performance through the first two parities.

(Key Words: Sows, Lactation, Lysine, Energy, Performance)

Introduction

The ability of sows to raise large litters and rebreed quickly following weaning is the key to improving the efficiency of a swine operation. Unfortunately delay in return to estrus is a common problem in primiparous sows (King and Williams, 1984a). This problem of increased interval to estrus is related to low intakes of dietary energy and(or) protein during lactation (Reese et al., 1982a,b; King and Williams, 1984b; Nelssen et al., 1985a; Brendemuhl et al., 1987). There have been several experiments attempting to determine which is more important energy or protein in improving sow reproductive performance. Protein intake appears

to offer the best opportunity to improve sow reproductive performance (King and Dunkin, 1986b; Brendemuhl et al., 1987).

Other factors influencing dietary energy and protein intake include type of feed, daily feed intake and environmental conditions (O'Grady, 1967). Fat has been added to lactating diets of primiparous sows to increase caloric intake and was shown to be beneficial in reducing the weaning to estrus interval in summer (Cox et al., 1983).

The objective of this experiment was to compare sow and litter performance through two parities when all sows were fed lactation diets formulated to meet or exceed NRC (1988) recommendations for lactating sows. Two dietary lysine levels (.65 and .75%) and two levels of added fat (0 or 3%) were utilized to determine if added lysine and(or) added dietary fat will, (1) improve sow or litter performance and (2) shorten the weaning to first estrus interval.

Experimental Procedure

General. One hundred fifty-eight crossbred sows (Duroc X Yorkshire X Chester White X Hampshire) were fed daily 1.8 kg of a 14% CP diet during gestation. On d 110 of gestation sows were moved into the farrowing crates and randomly allotted within replication to the lactation diets. There were four replications in each parity. For the 21-d lactation, corn-soybean meal diets were formulated to two lysine levels

(.65 and .75%) and two soybean oil levels (0 and 3%). Diets were analyzed for crude protein and complete amino acid profiles. Sows were fed the experimental diets ad libitum in two daily feedings from parturition until weaning. All sows received diets formulated to meet or exceed NRC (1988) recommendations for energy, protein, lysine, vitamins and minerals (Table. 1).

On d 110 of gestation and d 21 of lactation, a sample of venous blood was collected from the brachial region in an evacuated glass tube. Sows were bled 3 h after feeding. Blood samples were placed in an ice bath after collection and were stored over night at 4°C prior to centrifugation (1,400 X g for 20 min, at 2°C) to separate serum. Serum was frozen and stored at -20°C until analyzed for urea, creatinine and free fatty acid concentrations. Serum urea and creatinine concentrations were determined using a Rapid Flow Analyzer¹. Concentrations of serum urea nitrogen and creatinine were determined in serum by modifications of the procedures described by Marsh et al. (1965) and Chasson et al. (1961), respectively. Serum free fatty acid concentrations were determined colormetrically².

¹Alpkem Corp., Clackamas, OR.

²Wako Pure Chemicals Industries, Ltd., Osaka, Japan.

³Scanprobe, IthaCo Inc., Ithaca, NY 14850.

In addition, sows were probed ultrasonically³ (first rib, last rib and last lumbar vertebra) to determine backfat thickness on d 110 of gestation and d 21 of lactation. Sows and pigs were weighed within 24 h after parturition and on d 21 of lactation or on the date of weaning if less than 21 d. Creep feed was not offered to pigs and consumption of sow feed by pigs was considered minimal. Sows were drip cooled when temperatures reached or exceeded 29°C.

After weaning sows were placed in stalls or pens in an environmentally controlled building at weaning and fed 1.8 kg/d of a 14% crude protein gestation diet. Sows were checked for estrus twice daily in the presence of a boar beginning on d 2 after weaning and were considered to be in estrus when they stood in response to back pressure or mounting by a boar. Estrus detection was continued for sows not previously showing estrus for 28 d postweaning. Sows not exhibiting estrus by 28 d postweaning were slaughtered and reproductive tracts were examined for evidence of a functional corpus luteum.

All females were artificially inseminated with gilts being inseminated 8 to 16 h after estrus detection and sows 24 h after estrus detection. Gilts were reinseminated 8 h after initial service and sows were inseminated 24 h after the initial service. Beginning on d 15 and weekly thereafter all sows not exhibiting estrus were bled for progesterone analysis. Serum progesterone concentrations were determined by the method of Anthony et al.(1981). Serum progesterone

concentrations of greater than 2 ng/ml concentrations were considered indicative of ovulation 4 to 16 days earlier.

Parity one. The sows farrowed in March, April, May and June of 1988. Litter size was equalized within 2 d of parturition across all dietary treatments. Only the sows that had returned to estrus by d 15 postweaning were rebred and utilized for parity two.

Parity two. Eighty-seven sows that completed parity one, returned to estrus by d 15 and conceived on the first estrus following weaning were utilized for the second parity. In parity two, sows were fed daily 1.8 kg of a 14% crude protein diet during gestation and placed on the same lactation dietary treatment at parturition as they received in parity one. Litter size was equalized within dietary treatments by d 2 following parturition. Data collection in parity two was identical to parity one, with the exceptions that number of pigs born and number of pigs born alive were also recorded.

Statistical Analyses. The statistical model included all main effects and interactions. For sow and litter performance variables other than initial litter size and age at weaning, initial litter size and age at weaning were used as covariates. Initial litter size was used as a covariate to remove the variation in litter size on day 2 postfarrowing on subsequent sow and litter performance. Age at weaning was used as a covariate to remove the variance in age of pigs at weaning and the variation in lactation length. Probability

values for the covariates used are presented in tables 2, 3, 4 and 5. The data were analyzed using the GLM procedure of the Statistical Analysis System (SAS, 1985). Treatment effects on the percentage of sows exhibiting estrus by 7, 14, and 28 d postweaning was analyzed as categorical data using the procedure CATMOD of the Statistical Analysis System (SAS, 1985) in both parity one and parity two. Serum concentrations were tested by least-squares analysis of variance in both experiments.

Main effects and interactions in parity two were analyzed the same as parity one, except that only age at weaning was used as a covariate for sow and litter performance.

Results and Discussion

Parity one. The effect of dietary lysine and energy intake during lactation on primiparous sow performance is shown in table 2. There was no lysine by soybean oil interaction ($P>.23$) for feed intake, sow weight loss during lactation, sow backfat loss or weaning to first estrus interval in parity one.

In parity one, increasing dietary lysine from .65 to .75% had no effect ($P>.47$) on percentage of sows returning to estrus by d 14, however by d 28 fewer sows receiving the .75% lysine diet had returned to estrus ($P<.08$). Previous research by O'Grady and Hanrahan (1975), King and Williams (1984b) and

Brendemuhl et al. (1987) had found that sows receiving higher protein intakes returned to estrus quicker than sows on low dietary protein intakes during lactation. However, in these experiments sows fed the control diet were below dietary protein intakes recommended by the NRC (1988) for lactating sows.

Sows receiving .65% dietary lysine tended ($P<.11$) to have better conception rates than sows receiving .75% dietary lysine. This is in contrast to work by King and Dunkin (1986b) and Brendemuhl et al. (1987, 1989) in which protein was found to be more important in decreasing the weaning to estrus interval and improving sow reproductive performance when energy intake was 10 Mcal/d or higher. In our experiment, energy intakes were calculated to be at least 15 Mcal/d and CP intakes were calculated to range from 600 to 730 g/d. However, there was no effect of protein intake on the interval from weaning to first estrus. Brendemuhl et al. (1987) found that sows receiving the high energy-high protein diets had shorter intervals to first estrus. However, all other diets used by Brendemuhl et al. (1987) were well below the recommendations of NRC (1988) for energy and protein intakes.

In parity 1, there was a trend for fewer sows receiving the 3% soybean oil to return to estrus by d 7 postweaning ($P<.12$). Also, fewer sows receiving the 3% soybean oil returned to estrus ($P<.04$) by d 14 or d 28 postweaning. This is in agreement with results from Cox et al. (1983) which

showed a delay in return to first estrus when fat was added to sow lactation diets in winter. McGlone et al. (1988) also found a slight increase in weaning to first interval when fat addition was combined with drip cooling. The effect of fat addition on the weaning to first estrus interval has been very inconsistent as Shurson et al. (1986) found shorter weaning to first estrus intervals with addition of fat to multiparous sow lactation diets.

A total of 35 sows were bled for progesterone analyses in parity one. From this group of sows that were bled for progesterone analyses, only four of the sows that didn't exhibit estrus by d 28 were found to have either experienced silent estrus or were missed by the estrus detection procedures utilized (serum progesterone values >2 ng/ml). Furthermore, the sows that were slaughtered and found to have a functional corpus luteum were the same four sows that had elevated progesterone concentrations. These four sows were dispersed across all dietary lactation treatments.

Sows lost weight and backfat regardless of dietary treatment during lactation in parity one, however there was no dietary treatment effect ($P>.25$) on weight or backfat change (Table 2). Sow weight and backfat loss is not unexpected as primiparous sows are usually unable to consume the recommended energy intakes recommended by the NRC (1988). A shortage in energy intake during lactation has been shown to increase sow backfat and weight loss (Reese et al. 1982a,b;

Nelssen et al., 1985a,b; King and Dunkin, 1986a,b). Brendemuhl et al. (1987) and King and Williams (1984b) found sow weight loss was minimized when protein and energy intakes were high, while energy intake had more effect on backfat loss than protein intake. In our experiment energy intakes were at least 15 Mcal ME/d on all dietary treatments and there was no difference in backfat loss. Therefore, our data supports Brendemuhl et al. (1987) and King and Williams (1984b) findings that sow backfat loss during lactation is more dependent upon energy intake than protein intake.

There was no lysine X soybean oil interaction for lactational feed intake in parity one (Table 2). Increasing lysine from .65 to .75% had no effect on feed intake or caloric intake. This agrees with findings of the NCR-42 Committee (1978) and Shields et al. (1985) in which crude protein levels above 14% during lactation had no effect on feed intake, when sows received a gestation diet containing at least 14% crude protein. In contrast, Mahan and Grifo (1975) found a linear increase in sow feed intake as lactation diets increased from 12 to 18% crude protein. However, sows in their experiment received only an 8.2% crude protein diet during gestation and were deficient in protein intake prior to the initiation of lactation.

Lactational feed intake in parity one was reduced ($P < .05$) with the addition of 3% soybean oil, but caloric intake was not different ($P > .59$). Regardless of dietary treatment sows

consumed at least 15 Mcal/d of metabolizable energy in parity one. In agreement, Boyd et al. (1978, 1982) and McGlone et al. (1988) found that adding fat to lactation diets depresses feed intake. In contrast, Seerley et al. (1981), Cox et al. (1983) and Shurson et al. (1986) found no reduction in feed intake when fat was added to sow lactation diets.

Serum urea concentrations increased from d 110 of gestation to d 21 of lactation regardless of the dietary treatment in parity one (Table. 5). There was no lysine X soybean interaction ($P>.26$) in parity one for sow serum urea concentrations. Serum urea concentrations are used as an index to determine extent of amino acid catabolism (Reese et al., 1982a,b and Nelssen et al., 1985). Our data indicates that all sows catabolized amino acids during lactation, but there was no effect on amino acid catabolism rate due to increasing lysine level to .75% or addition of 3% soybean oil.

Brendemuhl et al. (1987) also found that serum urea concentrations increased as lactation progressed regardless of dietary treatment, and serum urea concentrations were highest on a low energy-high protein diet. Apparently more amino acids were catabolized on the low energy-high protein diet (Brendemuhl et al., 1987). In our experiment, lactational dietary protein intakes ranged from 600 to 730 g/d in parity one, however serum urea concentrations were unaffected by the different protein intakes. This indicates that intakes of 600

to 650 g/d of CP and 29 to 30 g/d of lysine are adequate for primiparous sows nursing nine or more pigs in a 21-d lactation.

In contrast, guidelines for intakes of 31 to 37 g/d lysine and 700 to 750 g/d CP were established previously in 4 to 5 wk lactations by King and Williams, (1984a,b) and King and Dunkin, (1986a). In parity one, our data indicated that there were no differences in serum urea concentrations when sow dietary lysine and CP intakes were increased to 33 to 35 g/d and 690 to 730 g/d respectively. Thus sows may have lower protein requirements in a 21-d lactation than longer lactations.

Serum creatinine concentrations (Table 5) remained constant from d 110 of gestation to d 21 of lactation in parity one, indicating no change in rate of muscle catabolism (Wallach, 1978). No dietary treatment effect on serum concentrations of creatinine was found in this experiment. Brendemuhl et al. (1989) found that sows receiving low protein intakes (<380g/d) catabolized more ($P<.05$) muscle than sows receiving high protein (>750g/d). Some of the difference in our findings can be attributed to Brendemuhl et al. (1987) using a longer lactation (28-d compared to a 21-d lactation) and a more varied sow protein intake. Based on creatinine concentrations in our experiment, we would conclude that a protein intake of at least 600 g/d is adequate to prevent severe muscle catabolism during a 21-d lactation.

Serum free fatty acid concentrations (Table 5) increased regardless of dietary treatment from d 110 of gestation to d 21 of lactation. There was no effect on serum free fatty acid concentrations due to dietary lysine or added dietary fat on d 21 of lactation. This was probably due to the similar sow caloric intakes throughout lactation, regardless of dietary treatment.

The effect of sow dietary intakes of lysine and energy during lactation on pig performance is shown in table 4. There was no lysine by soybean oil interaction ($P>.40$) for pig performance. Increasing lysine level to .75% had no effect ($P>.45$) on pig survivability, average pig weaning weight, 21-d litter weight or weaning litter size. Research by O'Grady and Hanrahan (1975), NCR-42 Committee (1978), King and Williams (1984b) and Brendemuhl et al. (1987) has shown increased pig and litter weight at weaning when sows consumed high intakes of protein (>500 g/d). However, these experiments were conducted using a 4 to 5 wk lactation, and differences were not evident in the first 21 d of lactation. Therefore, length of lactation and dietary protein intake during gestation are important in evaluating the effects of sow lactational protein intake on litter performance.

The addition of 3% dietary soybean oil during lactation had no effect ($P>.45$) on pig survivability, litter weaning weight or pig weaning weight. Pig survivability was high ($>90\%$) regardless of dietary treatment. Therefore, fat

addition to sow diets would not be expected to improve pig survivability (Pettigrew, 1981). Sow energy intakes were nearly equal among all dietary treatments and consequently there was no effect ($P>.45$) of energy intake on pig performance. In agreement, Pettigrew (1981), Seerley et al. (1981), Cox et al. (1983) and McGlone et al. (1988) found no improvement in pig performance with added fat during lactation. In contrast, Shurson et al. (1986) found increased pig performance when fat was added during late gestation and continued throughout lactation, due to the increased sow energy intake and higher milk yield. Schoenherr et al. (1989) also found an increased milk fat content when sows were fed fat in late gestation and throughout lactation. The increase in milk yield was not maintained throughout lactation. Increased milk yield with the addition of fat to diets appears to be dependent upon the addition of fat to sow diets during late gestation (Shurson et al., 1986; Schoenherr et al., 1989).

Parity two. The effect of lysine and energy intake during lactation on sow performance in parity two is shown in table 3. There was no lysine X soybean oil interaction ($P>.34$) for interval to first estrus, lactation weight change or lactation backfat change. There was no effect ($P>.12$) on percentage of sows returning to estrus by d 7, 14 or 28 postweaning due to increasing dietary lysine from .65 to .75%.

There was a trend for sows receiving 3% soybean oil to take longer ($P < .05$) to return to estrus than those sows receiving no soybean oil. The percentage of sows that returned to estrus by d 7 was lower ($P < .07$) for sows receiving 3% soybean oil. However, by d 14 and d 28 there were no differences ($P > .12$) among dietary treatments in the percentage of sows returning to estrus. By d 28, nearly all (greater than 94%) sows regardless of dietary treatment had returned to estrus.

In parity two, approximately 90% of all sows had returned to estrus by d 14 postweaning. Consequently only two sows were bled for progesterone analysis in parity two, and no behavioral estrus had been detected by d 28 postweaning in these two sows. Upon analysis, no increase in progesterone concentration was found. When slaughtered and upon examination of reproductive tracts, neither sow exhibited a functional corpus luteum. Both sows that failed to return to estrus received fat additions in their diets, however each sow received a different dietary lysine level.

Sow weight change and backfat change were not influenced ($P > .18$) by increasing dietary lysine from .65 to .75% (Table 3). There was no lysine X soybean oil interaction ($P > .11$) for sow weight change or backfat change. Sows in parity two had lysine intakes ranging from 34.5 to 41 g/d and CP intakes ranging 750 to 880 g/d, well above NRC (1988) recommendations. Daily protein and lysine intakes were at or above the

guidelines for dietary protein (700-750 g/d) and lysine (31-37 g/d) necessary to minimize sow weight loss and decrease the weaning to first estrus interval in lactating sows (King and Williams, 1984a,b; King and Dunkin, 1986a). Because of high protein (>750 g/d) and energy intakes (>17 Mcal/d) and the small litter size nursed, no differences were found in sow lactational weight or backfat change.

In parity 2, addition of 3% soybean oil to lactation diets had no effect ($P>.11$) on sow weight change or backfat change (Table 3) compared to no added soybean oil. Some sows gained weight and had increased backfat deposition during lactation due to small litter size nursed.

In parity two, lactational feed intake was not affected ($P>.09$) by either dietary lysine level or fat addition (Table 3). There was a lysine X soybean oil interaction ($P<.07$) for overall feed and caloric intake, however most of the interaction is likely due to the low number of sows on some dietary treatments. Shurson et al. (1986) and Schoenherr et al. (1989) also found no effect ($P>.10$) in feed intake when multiparous sows were fed diets with added fat. However, McGlone et al. (1988) reported a depressed feed intake when fat was added to diets of multiparous sows. Caloric intakes were high regardless of dietary treatment with all sows consuming at least 17 Mcal ME/d.

Serum urea concentrations increased from d 110 of gestation to d 21 of lactation regardless of dietary treatment

in parity 2. All sows catabolized amino acids, however there was no effect ($P>.23$) on the rate of amino acid catabolism due to dietary lysine or added soybean oil. There was a lysine X soybean oil interaction ($P<.07$) for serum urea concentration on d 21 of lactation, however the interaction was most likely caused by the variable litter size and low number of sows on some dietary treatments.

In our experiment lactational dietary protein intakes ranged from 750 to 880 g/d in parity two, however serum urea concentrations were unaffected by the different protein intakes. Protein intakes for all dietary treatments were at or above the 760 g/d protein intakes at which Brendemuhl et al. (1987) had shown increased serum urea concentrations. Thus it appears protein intakes on all dietary treatments were above the sows protein requirements.

In parity two, serum creatinine concentrations declined from d 110 of gestation to d 21 of lactation (Table 5). There was no effect ($P>.55$) on serum creatinine concentration due to increasing dietary lysine or soybean oil addition. There was no lysine X soybean oil interaction ($P>.58$) for serum creatinine concentration. With the small litters and the high intakes of energy and protein, sows lost very little weight or backfat and consequently catabolized very little muscle tissue.

Serum free fatty acids concentrations increased from d 110 of gestation to d 21 of lactation in parity two, however

there was no effect ($P>.17$) due to increasing dietary lysine or the addition of soybean oil (Table 5). There was a lysine X soybean oil interaction ($P<.10$) for free fatty acids, however this is most likely due to more variability in concentrations due to the small litter size and low number of sows on some dietary treatments.

The effect of sow dietary intake of lysine and energy during lactation on pig performance is shown in table 4. There was no lysine by soybean oil interaction ($P>.38$) for pig performance. Pig survivability, average pig weaning weight, 21-d litter weight and weaning litter size were not affected ($P>.10$) by dietary lactational lysine level. Litter weaning weights were numerically higher in parity 2 for sows fed the .75% lysine diets, however most of this increase was due to the numerically larger litter size at weaning. Heavier litter weaning weights due to increasing lysine level would agree with previous findings of King and Williams (1984b) and Brendemuhl et al. (1987) in which increasing protein intake increased litter weaning weights.

The addition of 3% dietary soybean oil during lactation had no effect ($P>.25$) on pig survivability, litter weaning weight or pig weight at weaning. Pig survivability was very high ($>91.8\%$) regardless of dietary treatment and addition of fat to sow diets during lactation should not increase pig survivability in herds with such a high survivability (Pettigrew, 1981).

In the second parity, litter size was low regardless of dietary treatment received in parity one, and there were no differences ($P>.56$) in number of pigs born due to the previous lactation treatment (Table 4). This agrees with previous research which indicates no effect on ovulation rate or subsequent litter size due to lactational dietary treatment (Elsley et al., 1968; O'Grady et al., 1973; Reese et al., 1982b; King and Williams, 1984b). Previously, Mahan and Mangan (1975) and Brendemuhl et al. (1987) had shown a decrease in subsequent litter size when sows had high protein intakes in the previous lactation. In our experiment, we found no dietary protein effect ($P>.57$) on the number of pigs born. Sows receiving .75% lysine in parity one actually farrowed numerically more live pigs and had a higher pig survivability rate ($P>.11$) in parity two compared to those fed .65% dietary lysine. Pig survivability was very acceptable and extremely high ($>91.8\%$) on all dietary treatments.

There was no season X diet interaction ($P>.20$) in the present experiment. Drip cooling was used during the summer months to alleviate heat stress. Drip cooling in summer appears to reduce seasonal effects (McGlone et al., 1988). In contrast, Allee and Salva (1978) and Cox et al. (1983) have shown a reduced interval to first estrus when fat is added to lactation diets in summer. Fat addition to sow lactation diets had been shown to be more beneficial in summer than winter (Allee and Salva, 1978; Cox et al. 1983; Schoenherr et al.

1989). Our findings of no seasonal effect from addition of fat to sow lactation diets agrees with the findings of McGlone et al. (1988) in which drip cooling eliminated any benefit of adding fat during heat stress.

The findings of the present experiment indicate no benefit for increasing the dietary lysine level above .65% or the addition of fat to lactation diets through the first and second parities. While our study was terminated after two parities, the effects of energy and lysine intake during lactation on sow and litter performance through several parities is needed.

Implications

Based on the findings of this experiment, the NRC (1988) recommendations of .60% lysine and 17.5 Mcal ME/d are adequate sufficient for sows nursing their first and second litters. A .65% lysine, corn-soybean meal diet without supplemental fat is adequate for sow and litter performance, when sows are drip cooled in times of heat stress and sow feed intake is at least 4.5 kg/d. Also, sows should receive a gestation diet containing at least 13% crude protein. Our data suggests that the addition of 3% soybean oil during lactation is not beneficial for sow or litter performance during the first two parities.

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Table 1. Diet Composition

Ingredient, %	<u>.65% LYSINE</u>		<u>.75% LYSINE</u>	
	Soybean	Soybean	Soybean	Soybean
	Oil	Oil	Oil	Oil
	0	3	0	3
Corn	81.39	78.05	78.06	74.74
Soybean meal, 48%	14.29	14.59	17.69	17.99
Soybean oil	0.00	3.00	0.00	3.00
Monocalcium Phosphate ^a	2.30	2.38	2.25	2.29
Limestone	1.02	0.98	1.00	0.98
Salt	0.50	0.50	0.50	0.50
Biotin	0.10	0.10	0.10	0.10
Vitamin Premix ^b	0.25	0.25	0.25	0.25
Trace mineral mix ^c	0.10	0.10	0.10	0.10
Selenium premix ^d	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Calculated Analysis,				
ME, Mcal/kg	3.27	3.38	3.27	3.38
Crude protein, %	14.00	14.00	16.00	16.00
Lysine, %	0.65	0.65	0.75	0.75
Ca, %	0.90	0.90	0.90	0.90
P, %	0.80	0.80	0.80	0.80

^aMonocalcium phosphate (21% P, 18.5% Ca).

^bComposition per kg of vitamin premix: 453,579 IU vitamin A; 45,360 IU vitamin D³; 1,814 IU vitamin E; 180 mg vitamin K; 454 mg riboflavin; 1135 mg pantothenic acid; 2495 mg niacin; 45,360 mg choline; 2.3 mg vitamin B₁₂.

^cComposition of trace mineral: 5% Ca, 10% Fe, 10% Zn, 10% Mn, 1% Cu, 0.3% I, and 0.1% Co.

^dComposition per kg of premix: 600 mg Se.

Table 2. Effect of Lysine Level and Supplemental Fat on Sow Performance During Lactation in Parity 1

Item	.65% LYSINE				.75% LYSINE				CV ^a , %	DAW	BLS	L	S	LxS	
	Soybean		Oil		Soybean		Oil								
	0%	3%	0%	3%	0%	3%	0%	3%							
Parity 1															
No. of litters	40	40	40	40	38	38	38	38							
Post farrowing wt, kg ^c	165.6	165.3	166.2	167.6	167.6	167.6	167.6	6.6	.028	.416	.470	.470	.720	.553	
Weaning wt, kg ^c	154.8	153.9	157.9	156.5	156.5	156.5	9.0	.001	.480	.198	.198	.198	.615	.913	
Wt. loss, kg ^c	10.9	11.3	8.3	11.0	11.0	11.0	113.4	.328	.009	.327	.327	.327	.396	.559	
Backfat loss, mm ^c	2.9	2.4	3.0	2.5	2.5	2.5	94.2	.901	.314	.881	.881	.881	.231	.851	
Feed intake (kg/d) ^c															
Week 1	4.7	4.5	4.6	4.4	4.4	4.4	17.2	.675	.034	.507	.507	.507	.151	.712	
Week 2	4.8	4.5	4.9	4.4	4.4	4.4	15.5	.292	.192	.694	.694	.694	.016	.965	
Week 3	4.6	4.4	4.6	4.3	4.3	4.3	19.2	.876	.177	.848	.848	.848	.050	.762	
Overall	4.6	4.5	4.7	4.4	4.4	4.4	13.3	.323	.034	.783	.783	.783	.032	.650	
ME, Mcal/g ^c	15.1	15.1	15.2	15.0	15.0	15.0	13.4	.316	.035	.789	.789	.789	.594	.657	
Percentage in estrus															
By d 7	58.5	45.2	53.7	42.1	42.1	42.1				.608	.608	.608	.115	.911	
By d 14	85.4	76.2	90.2	63.2	63.2	63.2				.479	.479	.479	.025	.239	
By d 28	95.1	83.3	90.2	71.1	71.1	71.1				.080	.080	.080	.037	.947	
Avg. days to estrus ^c	8.0	9.7	6.8	8.1	8.1	8.1	67.3	.352	.426	.125	.125	.125	.128	.709	

^aCoefficient of variation.

^bProbability values for the covariates: (DAW) days at weaning and (BLS) beginning litter size; and (L) lysine, (S) soybean oil and (LxS) lysine x soybean oil effects.

^cLeast-squares means.

Table 3. Effect of Lysine Level and Supplemental Fat on Sow Performance During Lactation in Parity 2

Item	.65% Lysine			.75% Lysine			P value ^b			
	Soybean		Soybean	Soybean		Soybean	AAW	L	S	LxS
	Oil	3%	Oil	0%	3%	Oil				
Parity 2	0%	3%	0%	3%	0%	3%	CV ^a , %			
No. of litters	28	23	19	17	17	17				
Post farrowing wt, kg ^c	183.4	184.5	187.0	187.4	187.4	187.4	6.6	.028	.416	.470
Weaning wt, kg ^c	154.8	153.9	157.9	156.5	156.5	156.5	9.0	.001	.480	.198
Wt. change, kg ^c	-1.6	+1.1	-4.9	-4	-4	-4	758.9	.383	.287	.111
Backfat change, mm ^c	-5	+5	-8	-8	-8	-8	824.1	.684	.197	.336
Feed intake (kg/d) ^c										
Week 1	5.0	5.2	5.1	5.0	5.0	5.0	15.5	.0008	.847	.462
Week 2	5.5	5.7	5.6	5.1	5.1	5.1	13.4	.169	.116	.091
Week 3	5.4	5.4	5.6	5.3	5.3	5.3	18.8	.823	.526	.665
Overall	5.3	5.4	5.5	5.1	5.1	5.1	12.8	.023	.771	.192
ME, Mcal/dc	17.3	18.2	18.0	17.1	17.1	17.1	12.7	.023	.747	.927
Percentage in estrus										
By d 7	85.7	56.5	84.2	76.5	76.5	76.5			.464	.064
By d 14	92.9	74.9	94.7	88.2	88.2	88.2			.400	.120
By d 28	100.0	95.6	100.0	94.1	94.1	94.1			.899	.740
Avg. days to estrus ^c	5.4	7.2	5.3	8.6	8.6	8.6	88.2	.292	.639	.048

^aCoefficient of variation.

^bProbability values for the covariate: (AAW) age at weaning and (L) lysine, (S) soybean oil and (LxS) lysine x soybean oil effects.

^cLeast squares means.

Table 4. Effect of Lysine Level and Fat Supplementation During Lactation on Litter Performance

Item	.65 Lysine			.75 Lysine			P values ^b				
	Soybean Oil	Soybean Oil	Soybean Oil	Soybean Oil	Soybean Oil	Soybean Oil	AAW	ILS	L	S	LxS
	0%	3%	0%	3%	3%	CV ^a , %					
Parity 1											
No. of litters	40	40	40	38							
No. of pigs equalized ^c	10.0	10.0	9.7	10.0							
No. of pigs weaned ^c	9.2	9.0	9.2	9.2			.110	.0001	.483	.603	.661
Pig survival, % ^c	92.0	90.1	92.3	91.8			.100	.227	.522	.526	.609
Pig performance, kg ^c											
21 day pig wt.	5.2	5.4	5.4	5.3			.0001	.0003	.863	.467	.408
21 day litter wt.	48.0	48.6	49.2	48.6			.0001	.0001	.706	.983	.783
Parity 2											
No. of litters	28	23	19	17							
No. of pigs born ^c	8.2	7.8	8.2	8.3							
No. of pigs born alive ^c	7.3	7.4	7.7	7.9			.004		.579	.772	.569
No. of pigs weaned ^c	6.8	6.8	7.5	7.3			.007		.273	.730	.835
Pig survival, % ^c	93.4	91.9	98.4	94.6			.590		.108	.802	.867
Pig performance, kg ^c									.105	.262	.633
21 day pig wt.	6.5	6.5	6.5	6.2			.0001		.447	.387	.383
21 day litter wt.	42.9	43.3	46.6	45.0			.667		.134	.609	.486

^aCoefficient of variation.

^bProbability values for the covariates: (AAW) age at weaning and (ILS) beginning litter size; and (L) lysine, (S) soybean oil and (LxS) lysine x soybean oil effects.

^cLeast squares means.

Table 5. Effect of Lysine Level and Supplemental Fat on Sow Serum Metabolites

Item	.65 Lysine				.75 Lysine				P values ^b			
	Soybean		Soybean Oil		Soybean		Soybean Oil		L	S	LxS	
	Oil	3%	Oil	3%	Oil	3%	Oil	3%				
Parity 1												
Urea, mg/dl ^c												
d 110	14.1	14.6	13.5	14.8	14.8	14.8	14.8	14.8	.784	.216	.618	
d 21	21.1	19.7	20.1	20.6	20.6	20.6	20.6	20.6	.929	.582	.269	
Creatinine, mg/dl ^c												
d 110	1.44	1.52	1.46	1.38	1.38	1.38	1.38	1.38	.285	.978	.115	
d 21	1.44	1.41	1.41	1.40	1.40	1.40	1.40	1.40	.651	.569	.818	
Free Fatty Acids, mEq/l ^c												
d 110	.089	.085	.091	.097	.097	.097	.097	.097	.221	.875	.422	
d 21	.182	.194	.191	.168	.168	.168	.168	.168	.584	.760	.285	
Parity 2												
Urea, mg/dl ^c												
d 110	14.0	13.4	12.2	14.1	14.1	14.1	14.1	14.1	.453	.347	.083	
d 21	22.7	19.8	21.1	21.7	21.7	21.7	21.7	21.7	.882	.230	.069	
Creatinine, mg/dl ^c												
d 110	1.66	1.66	1.67	1.75	1.75	1.75	1.75	1.75	.587	.637	.649	
d 21	1.33	1.26	1.30	1.30	1.30	1.30	1.30	1.30	.950	.558	.585	
Free fatty acids, mEq/l ^c												
d 110	.082	.082	.082	.082	.082	.082	.082	.082	.985	.999	.985	
d 21	.137	.150	.193	.143	.143	.143	.143	.143	.178	.320	.090	

^aCoefficient of variation.

^bProbability values for (L) lysine, (S) soybean oil and (LxS) lysine x soybean oil effects.

^cLeast squares means.

EFFECT OF DIETARY LYSINE AND ENERGY INTAKE DURING LACTATION
ON SOW AND LITTER PERFORMANCE
THROUGH THE FIRST AND SECOND PARITIES

by

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The effect of lysine and/or energy intakes on sow and litter performance during a 21 d lactation were examined through two parities. A 2 X 2 factorial design with four replications per parity was used. Dietary treatments consisted of two dietary lysine levels (.65 or .75%) and two soybean oil levels (0 or 3%). One hundred fifty-eight primiparous sows were utilized in parity one. Eighty-seven sows completed both parities. All females received 1.8 kg/d of a 14% CP diet during gestation and were fed the same lactation diet in both parity one and two. There was no lysine X soybean oil interaction for any of the criteria measured in either parity one ($P>.24$) or parity two ($P>.07$). Also, no diet by season interaction for any criteria measured occurred in either parity one or two ($P>.18$). In parity one there was no effect of dietary lysine or soybean oil on sow weight loss, sow backfat loss, pig survivability, weaning litter size, weaning litter weight, average pig weaning weight or percentage of sows returning to estrus by d 7 postweaning. Also, there was no effect of dietary lysine or soybean oil on serum concentrations of urea, creatinine or free fatty acids. Feed intake was depressed ($P<.05$) for sows receiving 3% soybean oil, however caloric intake was not affected by dietary soybean oil addition. Dietary lysine intake had no effect on daily feed intake or percentage of sows returning to estrus by d 14. However, fewer sows on the .75% lysine diet had returned to estrus by d 28 postweaning ($P<.08$). Addition of 3% soybean oil resulted in

fewer sows returning to estrus by d 14 and d 28 following weaning ($P < .03$). In parity two, there was no effect on sow or litter performance of either dietary lysine level or addition of 3% soybean oil, with the exception that sows receiving 3% soybean oil had a longer interval from weaning to estrus ($P < .05$). Based on the results of our experiment, we conclude that for a 21 d lactation a .65% lysine diet without added fat is adequate for sow and litter performance through the first two parities.

(Key Words: Sows, Lactation, Lysine, Energy, Performance)