EFFECT OF VARYING PROTEIN INTAKE ON REPRODUCTIVE PERFORMANCE OF SWINE, WITH EMPHASIS ON BODY FLUIDS AND THEIR COMPOSITION IN LACTATION

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled EFFECT OF VARYING PROTEIN INTAKE ON REPRODUCTIVE PERFORMANCE OF SWINE, WITH EMPHASIS ON BODY FLUIDS AND THEIR COMPOSITION IN LACTATION

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ABSTRACT

EFFECT OF VARYING PROTEIN INTAKE ON
REPRODUCTIVE PERFORMANCE OF SWINE, WITH EMPHASIS ON
BODY FLUIDS AND THEIR COMPOSITION IN LACTATION

N. S. Ramamurthy

Two experiments were undertaken to determine the effect of protein and lysine supplementation of the ration on the performance of sows in gestation and lactation.

Experiment 1, a 2x2 factorial with 2 replicates initially consisting of 8 gilts each, was carried through 3 consecutive reproductive cycles. Two levels of crude protein (CP) were fed in gestation (10.6 and 12.5%) and in lactation (10.8 and 15.7%).

Gestation and lactation performance, nitrogen retention and total body water were studied. The ration protein level did not influence the gestation or farrowing performance. However, the higher protein level in the lactation ration significantly ($P<0.05$) improved the weight gain of pigs at the 21st day of lactation. There was also a significant ($P<0.05$) gestation x lactation interaction. Nitrogen retention was significantly ($P<0.01$) higher for sows receiving 15% CP in the lactation ration. A higher level of CP in the gestation and/or lactation ration influenced the CP content, electrophoretic pattern of milk protein and amino acid content of sow milk. Percent body water and estimated body composition showed significant ($P<0.01$) changes in body composition

between the 3 periods. The results of Experiment 1 suggested that feeding 227 g CP/day in gestation followed by 15% CP in the lactation ration fed to appetite resulted in a higher weaning weight of pigs.

Experiment II was conducted using a completely randomized design. Sixteen Managra gilts (8/group) were used for 2 reproductive cycles. In gestation and in lactation a control ration (10.6 and 12.8% CP respectively) and a lysine supplemented (0.2%) control ration were fed. In addition to the parameters studied in Experiment 1 (except body water), plasma amino acid profiles were studied.

Lysine supplementation did not influence the gestation and farrowing performance. However, pigs from sows receiving 12.8% CP gained significantly ($P < 0.01$) more weight than pigs from sows receiving 12.8% CP plus lysine. Nitrogen retention was higher for the lysine supplemented group.

Three hours postprandial plasma amino acids were higher compared with levels after 18 hours fasting. Lysine supplementation increased the lysine plasma levels and decreased the threonine levels. This was significant ($P < 0.05$) only in gestation. Plasma amino acid levels were generally higher in lactation than in gestation. Supplementation of lysine in lactation did not show any beneficial effect to sows or their litters.

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INTRODUCTION

The success of a swine operation depends upon satisfactory reproduction in the sow. The more pigs produced and raised per sow, the smaller will be the maintenance cost per market pig produced.

In general, reproduction is a composite process dependent upon the nutritional status of the animal during growth, conception, pregnancy and lactation. A poor or inadequate nutritional regimen in any one of these periods, depending on its severity, may affect the reproductive performance.

The availability of crude protein (CP) is one of the factors which will determine the success of these physiological processes. Extensive research has been done on the protein and amino acid requirements for growing and finishing pigs. Recently some detailed studies have been carried out on the protein requirements during gestation. As a result of research in this area in the past decade, one can conclude that the crude protein requirement for gestation is not as high as has been recommended. Recent N.R.C. (1968) requirements indicated this by lowering the protein requirements for gestation. However, much more needs to be known about the amino acid requirements during gestation. In addition, few data are available on the protein and amino acid needs of lactating sows.

After considering the data available on the protein requirements for gestation and lactation a study was initiated to examine the protein requirements of reproduction with special emphasis on lactation needs. Two separate experiments were carried out. In Experiment 1, natural-type rations were used in gestation and lactation in which some animals were fed rations containing approximately the CP requirements recommended by N.R.C. (1968). Others were fed rations in reproduction with a lower CP content than N.R.C. (1968) requirements. In Experiment 11, lysine was added to natural-type rations for gestation and lactation which were lower in CP than the N.R.C. (1968) requirements.

During lactation, in addition to the normal performance data obtained, several biochemical criteria were considered. In order to better understand the protein metabolism of the lactating sow, nitrogen balances, milk protein composition and body composition were studied in Experiment 1. The same measurements were made in Experiment 11 and, in addition, fasting and fed plasma amino acid levels were studied. In both experiments it was recognized that the gestation ration could have a "carry over" effect on lactation performance. Consequently, the experiment was designed to permit the estimation of this effect in Experiment 1.

REVIEW OF LITERATURE

In reviewing the literature only the more detailed data will be discussed. Some of the data are concerned with a certain phase of gestation and a limited amount of data are concerned with lactation. Considerable data are available involving gestation-lactation studies and more recently, reports of studies involving several reproductive cycles have been published.

A. GESTATION

Mitchell *et al*. (1931) indicated that during gestation gilts tend to store nitrogen in the developing fetuses, placental membranes and uterus. Using a corn-based ration containing 11% crude protein (CP) they estimated nitrogen retention in gestating gilts as 7.12 g per day. After allowances for digestibility, biological value, and the use of a factor of 6.25 to convert the grams of nitrogen to grams of protein, their level of nitrogen retention was equivalent to a production requirement of 92 g CP per day.

Moustgaard (1956) estimated that the amount of nitrogen deposited in the uterus (fetuses and fetal membranes) of pregnant gilts, corrected to 10 fetuses each, was 50 g at approximately 70 days, 200 g at 100 days and 300 g at the end of gestation. Moustgaard considered the nitrogen deposited in the mammary gland would amount to approximately 5 g daily in the last 2 weeks of gestation. He concluded that a drastic rise in the protein requirement occurred after the 75th day of gestation. He estimated a minimum daily gestation requirement (production) for sows of 93.6 g CP per day which compares favorably to the data of Mitchell et al. (1931).

Lenkeit et al. (1955 ; 1956) obtained a positive nitrogen balance throughout gestation from sows fed 193 g CP, and increasing the daily intake to 662 g CP increased nitrogen retention only after the 90th day of gestation. They further observed a pronounced rise in nitrogen retention between the 95-100th day of gestation with the amount of nitrogen being closely related to the quantity fed.

It is quite interesting to note that the experimental results obtained by Lenkeit et al. (1955 ; 1956) were contradictory to those of Mitchell et al. (1931). Lenkeit et al. (1955 ; 1956) used sows as their experimental animals, while Mitchell et al. (1931) used gilts initially weighing 113 kg, and one would expect gilts of this weight to be growing with extra nitrogen being retained to meet this requirement. However, apparently this was not the case for these gilts which growing and producing a litter retained less nitrogen than sows which apparently showed little growth while producing a litter. The greater body weight of the sows could be a factor in their utilization and retention of extra nitrogen.

Rippel et al. (1965b) studied the protein requirement of gravid gilts. Cornstarch and corn were the primary energy sources while soybean meal was the protein source in the ration. Daily CP intakes ranged from 0-273 g from the 70th day of gestation to parturition. Two nitrogen balance studies were conducted, one starting from the 82nd day of gestation and the second on the 102nd day of gestation. It was found that nitrogen retention levelled off at an intake of 218 g per day on the 82nd and the 102nd day of gestation.

Milne (1965) studied nitrogen retention in pregnant sows fed 420 or 170 g CP daily. The main sources of CP were corn and alfalfa. Supplemental protein was provided in the high protein ration by soybean meal and meat meal. He found that nitrogen retentions were significantly lower for animals receiving the low protein ration.

It is interesting to note that gilts fed low protein by Rippel et al. (1965b) retained more nitrogen than sows fed by Milne (1965), even though the daily CP intake was approximately the same (170g). However, growing gilts would be expected to retain more nitrogen than sows. It should be noted that the amino acid balances of the rations fed were different. Rippel et al. (1965b) used a corn-soybean meal ration whereas Milne (1965) used corn and alfalfa meal as the sources of protein in the low protein ration. On the high protein ration, both gilts and sows showed similar results in terms of efficiency of nitrogen retention.

Salmon-Legagneur and Rerat (1962) found that the weight gained during gestation was due to a gain in weight of the carcass itself, in addition to the products of conception. Elsley et al. (1966) studied gestation weight gain and fed 308 g CP from a barley-fishmeal ration to six pregnant and six non-pregnant littermate gilts. They found that pregnant gilts retained 17 g nitrogen daily compared to 12 g by the non-gravid gilts. They also found significant differences in live weight gain, weights of the reproductive tract, mammary region and of the free draining blood between the pregnant and non-pregnant controls on the 110th day of gestation. Carcass analysis showed that in pregnant gilts 62.5% of the carcass was muscle and intramuscular fat compared to 60% for non-pregnant control. The results of these two experiments indicated that gestation anabolism not only affected the organs of reproduction but also the entire animal.

Miller et al. (1969) fed 114 to 342 g CP per sow per day using corn-soybean meal rations and found that maximum nitrogen was retained when gilts and sows were fed 285 g CP daily during gestation (to meet the protein requirements). This level of CP for maximum nitrogen retention is higher than the 218 g CP reported by Rippel et al. (1965b). The decreased efficiency of the former ration may have been due to a poorer balance of dietary amino acids. Soybean meal supplied 36.5 and 52.8% of the protein in the 12 and 15% CP rations, respectively, of Miller et al. (1969) as compared with 55.8% in the experiment of Rippel et al. (1965b).

In general, these studies have indicated a linear relationship between CP in the gestation ration and nitrogen retention. In addition to the products of conception during pregnancy, maternal tissue growth (ie. uterus) has been noted. However, no extensive information is available on the effect of various levels of protein on this growth. The significance of this growth is not clear, but Lenkeit et al. (1955b) noted that a well-fed sow in gestation (662 g CP daily) stored excess nitrogen in the body in addition to the products of conception. According to their data most of this nitrogen was lost in lactation and in the post weaning period.

Most of the experiments reviewed indicate that nitrogen retention during the last one-third of pregnancy levelled off at approximately 250 g of CP daily. A CP level in pregnancy as low as 150-170 g has not affected litter birth weight or survival rate. In summary, it cannot be stated precisely how much gestation anabolism and excess nitrogen is necessary for successful long-term reproduction.

B. GESTATION AND LACTATION

As mentioned earlier, reproduction is a continuous process and therefore performance during lactation must consider the environment of gestation including the gestation ration. In the following section, data concerning both gestation and lactation are discussed.

Clawson et al. (1963) studied the energy and protein requirements of gilts and sows in gestation. Using a semi-synthetic ration in which all the CP was provided by soybean meal, these workers obtained similar reproductive performance when comparing daily intakes of 136 or 545 g CP throughout gestation. There were significant differences in gestation weight gain but not in number or weight of pigs born or litter weight at eight-week weaning when a corn-soybean meal ration was fed ad libitum.

Rippel et al. (1965a) obtained normal reproduction in gilts and sows fed 92 g CP daily throughout the gestation period. Crude protein in the ration was provided by corn, soybean meal, sesame meal or gelatin, the last two of which are poor in essential amino acid balance. During lactation all these animals were fed ad libitum a 16% CP corn-soybean meal ration. Milne (1965) obtained similar results with gestating sows fed daily 170 g or 240 g CP from corn and alfalfa meal or 420 g CP from corn, alfalfa meal, soybean meal and meat meal rations.

Frobish et al. (1966) studied the gestation protein requirement of gilts fed 1.82 kg of a corn-soybean meal ration containing either 10 or 20% CP. In lactation a corn-soybean meal ration containing 15% CP was fed ad libitum. No significant differences in number of pigs farrowed alive, birth weight of live pigs or pig weight gain from birth to weaning were observed between the gilts fed a 10 or 20% CP ration in gestation. However, significantly more pigs were weaned from gilts fed 20% CP in gestation.

These data showed that, in short-term studies, both quality and quantity of protein in gestation did not influence the survival rate of the offspring and weight gain in subsequent lactation periods.

Holden et al. (1968) collected data on pregnant sows fed 1.82 kg per day of a corn-soybean ration containing 8, 12, 15 or 20% CP in lactation for four reproductive cycles. It was found that that the 8% CP ration did not prevent normal reproduction. However in lactation, there was a significant linear ($P<0.05$) increase in pig gain from birth to two week weaning with increasing protein level which levelled off at 16% CP. This difference in weaning weight could have some economic importance in a commercial swine operation.

Pond et al. (1968) reported that gilts fed essentially a protein-free ration starting on the 24-28th day of gestation farrowed normally. In lactation these gilts were fed a 12% CP corn-soybean ration and produced significantly less milk as indicated by the six week weaning weight of the offspring compared to offspring of the control-fed gilts. The latter received a 12% CP corn-soybean ration in gestation and lactation. It is conceivable that at a certain degree of amino acid deficiency during gestation, maternal tissues are sacrificed to an extent that subsequent lactation performance is impaired. The reciprocal transfer studies of Pond et al. (1968) suggest that severe protein and amino acid restriction during gestation affects the dam's capacity to lactate optimally rather than having some direct effect on the offspring. The pregnant sow may act as a buffer to protect the developing fetuses against the effect of maternal protein deprivation.

In the rat, however, Nelson and Evans (1953a) could not maintain gestation on a protein-free ration. Furthermore, they demonstrated (Nelson and Evans 1953b) that when rats were fed a 5% CP casein ration, a high percentage of resorption (70-100%), still births and low birth weight resulted. Other experiments revealed that gestating rats could be maintained on a protein-free ration with a daily administration of oestrone and progesterone (Hazelwood and Nelson 1965). Berg (1967) further showed that rats could maintain gestation with a transient supply of protein (20% CP casein) during the implantation period (3-5 days). In contrast to these data, with gilts fed essentially a protein-free ration, normal implantation occurred (Pond et al. 1968). Recently, Callard and Leatham (1970) showed that heavier-weight rats (250 g or more body weight) could complete pregnancy on a protein-free ration without hormone administration compared to lighter-weight rats (below 250 g body weight). They also showed that lighter-rats (180 g body weight) given 24 hours of artificial light daily throughout gestation completed gestation on a protein-free ration.

These data indicated that under normal circumstances rats were unable to complete gestation on a protein-free ration probably due to a limited supply of "reserve protein" because of the small metabolic body size and shorter gestation period in comparison to pigs. As a result, the rats were not able to accomodate the increased demand of gestation on a protein-free ration.

C. LACTATION

1. Protein requirement

Although there exists in the literature quantitative values for sow milk production, milk protein content, few data are available on the quality and quantity of protein necessary in the lactation ration to provide optimum milk production.

Salmon-Legagneur (1956) found a positive correlation between milk yield, the number of pigs at three weeks and the feeding regime in lactation. The utilization of dietary protein by lactating sows was studied by Gütte and Lenkeit (1957). They estimated that protein utilization in the lactating sow was 65% for maintenance and milk production using a natural-type ration.

Lodge (1959) studied the nitrogen balance and the protein requirement on the fourth and seventh week of lactation using three litter-mate sows. During the last 10 days of gestation and between the experimental periods, a barley-fish meal ration containing 16% CP was fed. During the experimental period, the sows were fed a barley-fish meal ration containing 11, 15 or 19% CP. The animals were kept at constant weight by *ad libitum* feeding. No beneficial effects were found when sows were fed more than 15% CP in the lactation ration.

MacPherson *et al.* (1969) studied the protein requirement of lactating sows with a ration containing 14% CP (barley-fish meal) fed to all animals during three successive pregnancies. During the six week lactation period, with litter size standardized at 9 pigs, sows received 5.3 kg of one of three rations containing either 14, 16.5 or 19% CP. As the CP level in the ration decreased the average six week litter weaning weight was significantly increased in the first lactation period. Similar but not significant differences existed in the second and third lactation periods. In general, the trend was for differences in weight gain to be smaller with each succeeding lactation period. There were no significant differences in milk yield or CP content of the milk in any lactation period.

While the data of Holden *et al.* (1968) were obtained over four reproductive cycles, unfortunately only performance data were collected. While milk protein contents were studied it would have been of additional interest if nitrogen balances, milk yield estimation and milk composition studies had been conducted for further comparison with the data of MacPherson *et al.* (1969) and other data published in the future.

2. Milk Yield

The literature regarding qualitative and quantitative aspects of sow milk has been reviewed by Duncan and Lodge (1960). In general, the sow's most productive period is between the third and fourth week of lactation when the sow produces between six and nine kg of milk daily. Milk samples can be obtained from sows by injecting oxytocin into the ear vein (Braude *et al.* 1947), but if milking is done by hand only a few teats can be milked because of the limited time of hormonal effect. To solve this problem a milking machine for sows was designed by Smith (1952) and modified by Hartman and Pond (1960).

3. Protein and Amino Acid Composition of Milk

The crude protein content of sow's milk has been determined by Braude et al. (1947), Perrin (1954) and others. These workers found that sow's milk contains approximately 5.3% CP in the third week of lactation and 8.3% in the eighth week with a simultaneous decrease in the quantity of milk produced. With a limited number of animals Lodge (1959a) could not influence the sow milk protein content by feeding 19% CP from a barley-fish meal ration in comparison to an 11% CP barley-fish meal ration.

Stothers and Milne (1964) fed a gestation ration containing 8% CP (corn) or 14% CP (corn-soybean-meat meal). A corn-soybean-meat meal ration containing 14% CP was fed during lactation to all sows. After one week of lactation, milk from sows fed the high protein gestation ration contained a higher level of CP, but this effect was not observed during the third week of lactation.

An increased milk protein level was noted by Holden et al. (1968) when sows were fed increasing levels of CP from a corn-soybean meal ration in gestation and lactation for four consecutive reproductive cycles. These workers did not comment on effect of age on milk yield and milk protein.

Beacom and Bowland (1951) reported the amino acid composition of sow milk protein. As a percent of protein, their values are comparable with human milk protein values reported by Morrison (1952). However, threonine, leucine, isoleucine and valine levels were slightly lower in sow milk protein.

D. AMINO ACIDS REQUIREMENTS IN GESTATION AND LACTATION

In spite of considerable research done on the amount of protein required for satisfactory gestation in swine, few data have been reported concerning the specific amino acid requirements for satisfactory reproduction. Ultimately, protein requirements for reproduction should be expressed in terms of amino acid requirements. Such data are expensive to obtain, particularly with large animals, so that data collected with laboratory animals should be of some assistance. In the following section, comments on some data from rats highlight some of the differences in reproduction between rats and pigs as well as some of the similarities.

Adams (1960) demonstrated an improved ovulation rate and 21st day embryo survival rate in swine when lysine was added to a 15% CP corn-sesame ration. Unlike the pig, in the pregnant rat the omission of tryptophan (Albanese *et al*. 1943) or methionine (Kemeny *et al*. 1953) from the ration led to reproductive failure but the addition of 0.2 or 0.4% methionine to a protein-free ration resulted in a normal pregnancy (Kinzey 1970). This evidence indicates the importance of certain essential amino acids for normal ovulation and maintenance of gestation in rats. The significance of this for swine reproduction remains to be more extensively tested.

Rippel et al. (1965c; 1965d) demonstrated that 0.42% lysine, 0.37% isoleucine, 0.28% methionine and cystine, 0.17% histidine, 0.30% phenylalanine, 0.01% tryptophan, 0.34% threonine and 0.46% valine were required in the ration for maximum nitrogen retention in gravid gilts at the 98th day post-coitum. The requirements for these amino acids are strikingly similar to those of finishing pigs (Becker et al. 1963).

Ting (1967) showed that the addition of 1.0% lysine-methionine mixture (lysine-methionine ratio 1.56: 1) and 1.0% diammonium citrate to a barley-maintenance ration (80 g CP per day) from the 90th day of gestation until farrowing did not influence sow weight gain, nitrogen retention or reproductive performance.

O'Grady (1967) studied the effect of lysine level in the lactation ration on the six week weaning weight of pigs. Sows fed 17% CP (lysine 0.52%) weaned heavier pigs than sows fed 13% CP (lysine 0.39%). By adjusting the fish meal content of the 13% CP ration the lysine level was increased to 0.52% and resulted in a litter weight gain at six weeks similar to those fed 17% CP. These experiments indicated for the first time the apparent importance of lysine in the lactation ration.

E. BODY COMPOSITION AND BODY WATER

The establishment of the exact nutritional requirement of the lactating sow would be facilitated and better explained if more precise information were available on changes in body composition associated with increase or decrease in the mother's body weight. Although body composition data are fairly extensive for animals at birth and near market weight, relatively little information is available covering the gestation and lactation phase of reproduction.

The literature on body composition in farm animals and man has been extensively reviewed by Reid et al. (1968). Early workers studied body composition of animals by use of the slaughter technique and this method is still extensively used.

Body water and body fat are negatively correlated (Clawson et al. 1955; Gnaedinger et al. 1963). By determining body water the whole body composition can be calculated without slaughtering the animals.

Since 1940 various chemicals have been used to determine body water. The determination of body water is based upon the assumption that an injected chemical is distributed rapidly and uniformly throughout the body. It must also be metabolized at a uniform rate from the body. Furthermore it should not be hazardous to the experimental animal and not normally present in the body in appreciable amounts.

Total body water can be determined by injecting a chemical into the blood. A number of samples are removed over a period of time and analyzed. The values obtained are plotted on a regression line and extrapolated to zero time. A number of chemicals have been tried by various workers. Of these, deuterium and tritium best meet the above assumptions. However, determination of deuterium involves using a mass spectrometer which is outside the scope of most laboratories. This leaves tritium as the first choice and several workers have used it to measure body water in pigs (Hansard 1964; Kay et al. 1966). The main disadvantages of tritium are the cost of liquid scintillation counters and over-estimation of body water because of tritium exchange with hydrogen atoms in protein and fat.

F. PLASMA AMINO ACIDS

Longenecker and Hause (1959) have shown that with dogs a postprandial alteration in plasma amino acid levels occurs following ingestion of protein. The literature on protein nutrition and free amino acid patterns has been reviewed by Leatham (1968).

Richardson et al. (1965) studied the concentration of plasma amino acids in 10 week old pigs (28 kg) receiving three levels of dietary protein. In their study they fasted the animals at different times and determined the plasma amino acid levels at 0, 12 and 24 hours. In the experiment involving three levels of dietary protein, significant increases in glutamic acid, isoleucine, ornithine, threonine, tyrosine and valine occurred as the protein level increased from 0 to 15% and from 15 to 30%. Morrison et al. (1961) with growing rats and Zimmerman and Scott (1965) with chicks presented evidence to show that when an amino acid is added in graded levels to a diet deficient in this amino acid, the plasma concentration of the amino acid remains rather low and constant until the dietary requirement is reached. Subsequently there is a rapid and linear increase in the concentration of the amino acid in the plasma as levels above the requirements are fed. Using this technique Mitchell et al. (1968) reported the dietary requirement of certain amino acids for a growing pig (10 kg) to be as follows: lysine 0.86%, isoleucine 0.46%, leucine 0.78% and histidine 0.27%. These levels are close to the estimated requirements obtained by nitrogen balance trial. Lucas et al. (1969) determined the plasma amino acid concentration of sows during gestation and lactation. Sows were fed a semi-purified or a corn-soybean ration containing 8, 12, 16 or 20% CP. In the pooled plasma sample, they observed that levels of essential amino acids (except methionine, histidine and phenylalanine) increased linearly with increasing levels of protein in the ration; methionine, histidine and phenylalanine levels increased quadratically. The levels of plasma amino acids were significantly lower in lactation than gestation. These workers collected the gestation blood samples one hour after feeding and lactation blood samples were collected three hours postprandial. The differences found in plasma amino acid levels in gestation and lactation may be the result of differences in sampling time.

Thus, the plasma amino acid levels are another parameter for assessing the protein status of an animal and should assist in estimating the protein requirement under study.

EXPERIMENTAL

A. OBJECTIVE

Two experiments were undertaken to determine the effect of protein and amino acid supplementation of the ration on the performance of sows in gestation and lactation with the most extensive performance and biochemical data obtained for the latter.

Most of the protein in the ration was supplied by barley with a smaller amount supplied from wheat or corn in some lactation rations. Supplemental protein was provided from soybean meal and L-lysine was the supplemented amino acid.

B. EXPERIMENT 1

Sixteen gilts of the Managra strain were selected for study during three consecutive reproductive cycles. In November 1967, eight gilts initially weighing 90 kg, were allotted to their respective treatments and approximately two months later they were bred at an average weight of 150 kg (Replicate 1). In July 1968 a second group of eight gilts weighing 90 kg were selected and allotted to their respective treatments and bred at an average weight of 110 kg (Replicate 11). Throughout the experiment Yorkshire boars were used for all matings.

1. Rations

The rations used in Experiment 1 are shown in Table 1. In lactation, wheat or corn was used to adjust the protein content to approximately 10% because of variation in the protein content of the barley. When corn was used, 0.1% lysine was added to maintain a relatively constant lysine level. Soybean meal in the high protein ration was similarly adjusted in lactation.

During gestation and lactation the sows were individually fed. In gestation, 2.27 kg of ration was fed daily while in lactation sows were fed to appetite with the exception of Cycle 1. Sows from Replicate 1, Cycle 1 were fed 3.63 kg of the lactation ration. Since this experiment was designed to study the protein requirement of sows in lactation no creep ration was supplied to the young pigs.

2. Experimental Design

A 2 x 2 factorial experiment was used in which 16 gilts were randomly allotted to a treatment combination with the restriction that littermates and initial weight variation were distributed as uniformly as possible among the treatments. Thus, four gilts ie. four from each replicate received either the 10% CP ration (low) or 12% CP ration (high) in gestation. In lactation, gilts from each gestation treatment were divided

Table 1. Composition of Gestation and Lactation Rations - Experiment 1

	Gestation		Lactation	
Crude Protein (%)	High(12.5)	Low(10.6)	High(15.7)	Low(10.8)
Ingredient (%)				
Barley	82.5	88.5	78.5-80.5	75.5-76.5
Alfalfa meal	10.0	10.0	-	-
Soybean meal[1]	6.0	-	20.0-18.5	-
Wheat[1]	-	-	-	23.0-22.0
Lysine	-	-	-	0.1
Di-calcium phosphate	0.5	0.5	0.5	0.5
Limestone	1.0	1.0	1.0	1.0
Salt	0.5	0.5	0.5	0.5
Vitamin A	-	-	+	+
Vitamin D_2	+	+	+	+
Vitamin B_{12}	+	+	+	+

[1] Due to the high protein content in 1968 wheat and barley, wheat was replaced by corn plus 0.1% lysine to maintain a constant protein and lysine level in the low protein ration. Barley and soybean meal were adjusted to maintain a constant protein level in the high protein ration.

Note: Dry vitamins A, D_2 and B_{12} were added to supply 3,300 I.U., 396 I.U. and 11 ug respectively per kg of ration.

into two groups and received either a 10% CP (low) or a 15% CP (high) ration. Hereafter, the following abbreviations will be used to refer to the gestation-lactation treatment combinations: low-low, low-high, high-low and high-high.

During pregnancy all sows were weighed every two weeks. Approximately one week before farrowing each sow was moved to a farrowing crate and remained there until her litter was weaned at three weeks of age. Within 24 hours after farrowing, the sow and new born pigs were individually weighed. All the new born pigs were ear notched for identification and injected with 150 mg of iron dextran within 24 hours. Similarly, weights were obtained at 7, 14 and 21 days of lactation. Sows were not bred until about 25 days after weaning. They were individually weighed at 14 days after weaning and this weight was used for body composition studies.

3. Digestibility, Nitrogen Balance and Milk Studies

These studies were conducted on all animals starting at the end of the 14th day of lactation at which time the sows were fed a ration containing 0.5% chromium oxide. Three days after feeding the chromium oxide, fecal samples were collected for three consecutive days and stored as described by Milne (1965). Simultaneously, urinary catheters were introduced and urine was collected for three days by the method outlined by Cunningham (1955). Milk yield was estimated between the 17th and 19th day of lactation by weighing the young pigs before and after they suckled their mother during a 4 hour period (Berge and Indrebo 1953).

Milk was collected from the sows on the 21st day of lactation. The milk collection was carried out using a milking machine as described by Pond et al. (1962). Teat cups were slightly modified however, in that teflon tubing was used for the teat cups and soft rubber tubing was used as a lining. Milk was collected from all active mammary glands and a 150 ml pooled sample was taken immediately and frozen until analyzed.

Nitrogen in the feed, feces, urine and milk was determined by the macro Kjeldahl method described by the Association of Official Agricultural Chemists (1960). Chromic oxide in the feed and feces was determined by the method described by Williams et al. (1962). Samples of the ration and milk were hydrolyzed for amino acid analysis by a modification of the procedure of Bragg et al. (1966). Hydrolyzing time was 15 hours for the feed and 10 hours for the milk samples. Amino acids were eluted with a pH 2.2 sodium citrate buffer and were determined by the method of Benson and Patterson (1965a). Milk proteins were fractionated by the polyacrylamide gel electrophoresis technique described by Hartman and Swanson (1965) and were scanned in a Densitometer.

4. Total Body Water Determination

Total body water of the sows was estimated by the procedures outlined by Hansard (1964) and Kay *et al.* (1966) using tritiated water. Body composition was deduced from body water using the procedure of Clawson *et al.* (1955) modified by Gnaedinger *et al.* (1963). The total body water was estimated on the first day of lactation, 12 hours after weaning and 14 days after weaning for two lactation periods. Blood samples were prepared using the method of Werbin *et al.* (1959) and were counted in a Nuclear Chicago liquid scintillation counter using the channel ratio method.

C. EXPERIMENT 11

The results of Cycles 1 and 2, Experiment 1 indicated a need to test another lactation protein level between 10 and 15% CP. Thus, a second experiment was designed to test a ration containing 12-13% CP. Sixteen Managra gilts with an average weight of 120 kg were selected for study during two reproductive cycles. These gilts were also bred to a Yorkshire boar. During gestation a barley-corn ration was fed as a control ration and 0.2% L-lysine was added to the control ration since lysine was limiting in the barley protein. During lactation a barley-soybean meal (12%) ration was fed as a control ration and 0.2% L-lysine was added to this ration

Table 2. Composition of Gestation and Lactation Rations - Experiment 11

	Gestation		Lactation	
Crude Protein (%)	Control (10.6)	Control plus Lysine (10.9)	Control (12.8)	Control plus Lysine (12.8)
Ingredient (%)				
Barley	75.0	74.8	94.0	93.8
Corn	23.0	23.0	-	-
Soybean meal	-	-	4.0	4.0
Lysine	-	0.2	-	0.2
Di-calcium phosphate	0.5	0.5	0.5	0.5
Limestone	1.0	1.0	1.0	1.0
Salt	0.5	0.5	0.5	0.5
Vitamin A[1]	-	-	+	+
Vitamin D_2	+	+	+	+
Vitamin B_{12}	+	+	+	+

[1] Gestation rations were low in Vitamin A.

Note: Dry vitamins A, D_2 and B_{12} were added to supply 3,300 I.U., 396 I.U. and 11 ug respectively per kg of ration.

to keep the lysine level equal to that of the 15% CP ration of Experiment 1.

A completely randomized design was used in this experiment. The weighing and general management of the sow and pigs were the same as in Experiment 1. In lactation performance data, nitrogen balance and milk production were studied as in Experiment 1. Body water determinations were not carried out, but plasma amino acid studies were conducted both in gestation and lactation.

1. Determination of Amino Acids in Blood Plasma

Blood samples were collected 18 hours after fasting and 3 hours postprandial between the 90-98th day of gestation and on the 21st day of lactation. Approximately 10 ml of blood were collected in a graduated centrifuge tube containing potassium oxalate and centrifuged at 1,960 x g for 10 minutes. The plasma was removed and deproteinized by the Van-Slyke and Hawkins (1928) modification of the Folin and Wu (1919) method. Five ml of protein-free filtrate was lyophilized. The dry residue was dissolved in two ml of 2.2 N sodium citrate buffer and 0.5 ml of this solution was analyzed for amino acids in a Model 116 Beckman Amino Acid Analyzer. Amino acid analysis was carried out using the method of Benson and Patterson (1965b) with the following modification. A buffer of 3.17 pH with a 0.2 N sodium citrate concentration was initially used. After

85 minutes the buffer was changed to 4.25 pH with a 0.2 N sodium concentration. A 6.3 pH buffer with a 0.4 N sodium concentration was used after 138 minutes. All the amino acids except arginine were eluted from the column in 310 minutes.

2. Statistical Analyses

Statistical analyses of the data (Experiments 1 and 11) were carried out according to the methods of Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

A. EXPERIMENT 1

1. Gestation and Farrowing Performances of Gilts and Sows

There were no significant differences between rations in gestation weight gain of the pigs in any period (Table 3). However, during the second and third periods the pigs which were receiving a low protein ration showed a lower weight gain whereas during the fourth period the low protein treatments gained slightly more than the animals fed the high protein ration. In this period both treatment groups gained less compared to previous periods, since the fourth period was a 20 day period rather than the 30 days for each of the first three periods.

Overall, the total weight gain and average daily weight gain in gestation were slightly higher for sows receiving 12% CP than for sows receiving 10% CP. Similar results were obtained by Rippel *et al*. (1965a) when bred gilts and sows were fed 5 or 16% CP using a corn-soybean base for the ration. Frobish *et al*. (1966) noted no significant difference in gestation weight gain of sows fed 182 or 364 g CP daily from a corn-soybean ration.

Table 3. Mean Period, Total and Daily Weight Gain (Kg) of Pregnant Gilts and Sows During Three Reproductive Cycles - Experiment 1

Protein Level in Gestation (%)	High (12.5)	Low (10.6)
Number of pigs (gilts and sows)	21[1]	22[1]
Initial weight	156.9±5.2[2]	154.2±5.0[2]
Period weight gain[3]		
First	15.1±1.1	12.2±0.9
Second	15.8±2.4	12.2±1.1
Third	15.3±1.3	14.5±1.1
Fourth	9.9±1.5	11.1±1.3
Total weight gain	56.1±7.9	53.4±6.2
Av. daily wt. gain	0.50±0.02	0.48±0.02

[1]One sow from each of the high and low protein treatments died after the first lactation due to broken pelves. In the second lactation a third sow from the high protein treatment was removed because she was a repeat breeder.

[2]Mean ± standard error

[3]Period weight gain for gilts and sows consisted of 28-30 days except for the fourth period which consisted of 20-21 days.

Note: All the gilts and sows were hand fed 2.27 kg of gestation ration daily.

The weight loss of sows after farrowing did not show any significant treatment difference (Table 4). The number of pigs born alive was slightly higher for sows receiving 12% CP during gestation compared to sows receiving 10% CP in gestation. However, the birth weight and average live birth weight of pigs were almost identical for the two ration treatments.

Milne (1965) observed no significant differences in number of live pigs born or birth weight when dams were fed as low as 170 g CP from a corn-based ration. Holden et al. (1968) also obtained similar results using corn-soybean rations containing 8 to 20% CP. Clawson et al. (1963) also reported comparable results when pregnant gilts were fed as low as 136 g CP daily with a low energy intake.

2. Lactation Performance

As mentioned earlier in the experimental procedure, during lactation each gestation treatment group was divided into two groups, one group receiving a barley-soybean ration (high protein - 15% CP) and the other group receiving a barley-based ration (low protein - 10% CP).

The results showed that neither gestation protein level nor lactation protein level influenced the three week litter size (Table 5). However, the treatment group which received a higher level of protein both in gestation and lactation

Table 4. Mean Farrowing Performance of Sows and Litters for Three Reproductive Cycles - Experiment 1

Protein Level in Gestation (%)	High (12.5)	Low (10.6)
Number of litters	21[1]	22[1]
Farrowing wt. loss, kg	16.7±0.8[2]	16.5±0.6[2]
Number of pigs born per litter	11.5±0.7	11.1±0.4
Number of pigs born alive	10.7±0.6	10.5±0.4
Birth weight of pigs, kg	1.41±0.06	1.39±0.04
Birth weight of pigs born alive, kg	1.41±0.06	1.41±0.04

[1] One sow from each of the high and low protein treatments died after the first lactation due to broken pelves. In the second lactation a third sow from the high protein treatment was removed because she was a repeat breeder.

[2] Mean ± standard error

Table 5. Means for Three Week Lactation Performance of Litters from Three Reproductive Cycles* - Experiment 1

Protein Level in a) Gestation (%)	High (12.5)		Low (10.6)	
b) Lactation (%)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)
No. of litters	12	9[1]	12	10[1]
No. of pigs weaned / litter	9.3 ±0.6[2]	8.7 ±0.8	8.4 ±0.7	8.7 ±0.5
Pigs' cumulative weekly wt. gain, kg				
First week	1.02±0.11	1.25±0.13	1.24±0.11	0.97±0.13
Second week	2.19±0.19	2.30±0.18	2.40±0.15	1.84±0.17
Third week	3.27±0.23[ab]	3.25±0.36[ab]	3.66±0.31[aA]	2.63±0.14[bB]
3 wk. cumulative litter weaning wt. gain, kg	28.6 ±1.0[a]	27.2 ±3.0[a]	29.5 ±1.9[a]	23.1 ±2.0[b]

*Means having different upper case superscripts differ significantly, $P<0.01$
Means having different lower case superscripts differ significantly, $P<0.05$

[1] One sow from each of the high-low and low-low treatments died after the first lactation due to broken pelves. In the second cycle a third sow from the high-low treatment was removed because she was a repeat breeder.

[2] Mean ± standard error

weaned slightly more pigs than the other treatment groups. Similar results were obtained by Holden et al. (1968) using a two week lactation period and MacPherson et al. (1969) where a six week lactation period was used.

The weight gain of the nursing pigs after one week of lactation showed no significant difference between treatments. However, the pigs nursing the sows receiving the low-low protein treatment gained less compared to the other treatments. This difference becomes accentuated by the end of each succeeding week so that after three weeks lactation the cumulative weight gain was significantly ($P<0.01$) less than pigs nursing sows on the low-high treatment. In addition there was a significant ($P<0.05$) gestation x lactation treatment interaction indicating the carry over effect of the gestation protein level on lactation performance (Appendix Table 5). The three week cumulative weaning weights of the pigs nursing sows receiving the high-high and high-low treatments were not significantly different from the low-high or from the low-low treatments.

However, when the number weaned in each treatment was combined with their average weaning weight to determine the three week cumulative litter weaning weight gain a different result was noted. In this instance, the litter weaning weight for the nursing pigs from the low-low treatment was significantly ($P<0.05$) lower compared with the other ration treatments.

The results of MacPherson et al. (1969) were opposite to the above finding. Thus, sows receiving a lower protein level weaned a heavier litter. However, MacPherson et al. (1969) used fish meal as a supplementary protein source to formulate lactation rations containing 14, 16.8 and 19% CP Thus, the lower level of protein used in MacPherson and co-workers' (1969) study is approximately the crude protein content of the high protein lactation ration used in this study. It should also be noted that MacPherson et al. (1969) conducted their study over a 42 day lactation period compared to the 21 day lactation period used in this study.

To assist in the explanation of litter data, the sow data are of interest (Table 6). The lactation feed intake data showed no significant difference among rations. The lack of any great difference in feed consumption could be attributed in part to similar sized litters weaned by all ration treatments. However, it is of interest to note the greater difference in feed consumption during the nitrogen balance trial (17th-20th days) on which more comment will be made later.

The estimation of milk yield and crude protein indicated no significant difference between the four ration treatments. However, milk from the low-low treatment contained a CP level consistently lower when compared to the other treatments.

Table 6. Means for Three Week Lactation Performance of Sows from Three Reproductive Cycles - Experiment 1

Protein Level in a) Gestation (%)	High (12.5)		Low (10.6)	
b) Lactation (%)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)
No. of sows	12	9[1]	12	10[1]
Feed intake, kg	4.66±0.27[2]	4.63±0.24	4.79±0.26	4.84±0.26
Milk yield, kg[3]	6.98±0.80	6.55±0.43	6.36±0.43	6.46±0.80
Milk protein, %[4]	5.34±0.24	5.35±0.16	5.38±0.16	4.97±0.29
Sow weekly wt. loss, kg				
First week	-7.36±2.78	-9.52±3.17	-7.35±3.80	-7.58±4.70
Second week	-8.41±2.46	-8.53±2.07	-9.09±2.54	-7.14±2.34
Third week	-11.85±4.56	-18.43±5.32	-16.13±2.22	-12.23±4.28

[1] One sow from each of the high-low and low-low treatments died after the first lactation due to broken pelves. In the second cycle a third sow from the high-low treatment was removed because she was a repeat breeder.

[2] Mean ± standard error

[3] Milk yield was estimated between the 17th and 20th days of lactation.

[4] Milk samples were collected on the 21st day of lactation.

Milne (1965) showed that after one week's lactation, the young pigs of sows which received the low protein ration in gestation received almost identical quantities of milk as young pigs nursing sows which received a high protein gestation ration. However, due to a lower protein content of the milk produced from feeding the low protein ration, young pigs from this treatment received significantly ($P<0.05$) less milk protein at one week of lactation. This difference did not exist by the third week of lactation, undoubtedly related to the fact that all sows received a high protein ration in lactation and some adaptation probably occurred between the first and third week. The present study, which in part was designed to study any carry-over effect of gestation protein level, confirms Milne's (1965) finding. This difference in milk protein level after three weeks lactation, though not significant, could be a factor in explaining the lower three week litter weight gain when sows were on the low-low treatment.

Weight losses by the sows did not show any consistent trend throughout lactation. During the first two weeks of lactation the weight losses by the sows were almost identical for all ration treatments. However, in the third week, sows which weaned heavier pigs lost the most weight. Since the sows on the low-low treatment lost a similar amount of weight to those on the high-high treatment apparently they did not utilize much body tissue for milk production which might have helped to equalize all litter weaning weights. It could be rationalized that if the nutrients were not available in feed, sows on the low-low treatment might have lost the most weight in lactation in order to meet litter needs. The live weight changes of the sows that completed all three reproductive cycles are shown in Figure 1. In Cycle 1 there were no differences in the live weight changes. However, in Cycles 2 and 3 the sows which were fed the high protein ration in gestation gained the most.

3. Nitrogen Balance Trials

As noted earlier sows fed a low protein ration in lactation ate slightly more feed daily during lactation in order to help meet the lactation protein requirement (Table 7). Again, though the difference in feed consumption was not significant, in the nitrogen balance trial sows on the low protein lactation ration ate approximately 5.25 kg daily compared with 4.55 kg for sows on the high protein ration.

Due to differences in CP content of the feed the nitrogen intake was 27 g higher for the high protein lactation treatments. As expected nitrogen absorption was proportional to nitrogen intake and was significantly higher ($P<0.05$) for the high protein treatments. Apparent digestibilities (ie. nitrogen absorption) were 78 and 77% for the high and

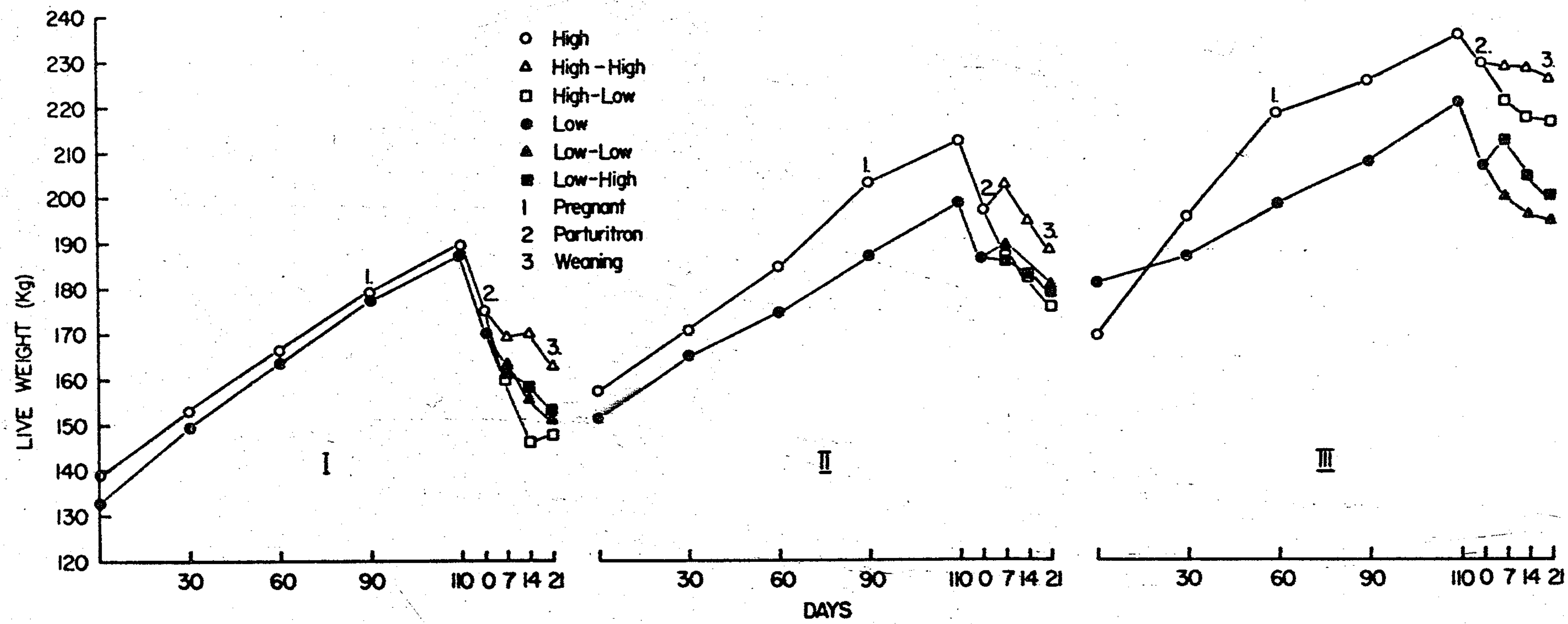

Figure 1. Live Weight Changes of Gilts and Sows in Three Reproductive Cycles - Experiment 1

Table 7. Means of Daily Nitrogen Balance Trial Data from 17th-20th Days of Lactation* - Experiment 1

Protein Level in a) Gestation (%)	High (12.5)		Low (10.6)	
b) Lactation (%)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)
No. of litters	8[1]	9	9[1]	8[1]
Feed intake, kg	4.39±0.42[2]	5.06±0.34	4.71±0.34	5.44±0.42
Nitrogen intake, g	108.7 ± 5.0^{A}	82.5 ± 4.5^{B}	113.3 ± 4.5^{A}	84.8 ± 5.0^{B}
Apparent nitrogen absorbed, g	84.0 ± 5.4^{A}	65.2 ± 5.1^{B}	87.8 ± 5.1^{A}	64.7 ± 5.4^{B}
Nitrogen in urine, g	19.9 ±3.4	26.8 ±3.2	29.6 ±3.2	22.9 ±3.4
Nitrogen in milk, g	55.3 ±3.7	55.2 ±3.5	55.8 ±3.5	49.1 ±3.7
Nitrogen retained, g	8.50 ± 6.16^{aA}	-16.66 ± 6.38^{bB}	1.29 ± 6.38^{ac}	-8.85 ± 6.16^{bc}

*Means having different upper case superscripts differ significantly, $P<0.01$
Means having different lower case superscripts differ significantly, $P<0.05$

[1] Four sows from high-high, three sows from low-high and two sows from low-low treatment were not included in the nitrogen balance trial due to a shortage of metabolic cages.

[2] Mean ± standard error

low protein treatments respectively.

There was no consistent pattern in urinary nitrogen excretion. However, the high-high protein treatment excreted almost as much urinary nitrogen as that of the low-low protein treatment. There were no significant differences in nitrogen secretion in milk, although the low-low treatment excreted 6 g less nitrogen in terms of milk protein when compared to the other treatments. Milk yields were obtained over a four hour period and the results extrapolated to 24 hours.

Nitrogen retention was significantly higher ($P<0.01$) for the groups receiving the high protein lactation ration compared with the groups receiving the low protein lactation rations. The low protein groups were in negative nitrogen balance compared with a positive balance for the high protein groups.

Gütte and Lenkeit (1957) reported the efficiency of conversion of dietary protein for maintenance and milk production as 65%. Using the same concept, MacPherson et al. (1969) reported an efficiency of conversion of dietary protein into sow milk protein as 38.4%. The efficiencies of conversion of dietary protein into sow milk in the present experiment were 53.9, 64.3, 46.3 and 54.7% for the high-high, high-low, low-high and low-low treatments respectively. These efficiencies are quite high compared to the results of

MacPherson et al. (1969) whose low protein treatment group received 746 g CP daily compared with 689 g by the high protein lactation groups in the present study. The higher value in the present study could be due to utilization of body reserves. If body weight loss is an indication of body reserve utilization, all the animals in the experiments reported here lost more weight in three weeks' lactation in comparison to sows in six weeks' lactation as reported by MacPherson et al. (1969) The treatment which lost the most weight (high-low) in three weeks of lactation showed the greatest efficiency.

4. Protein and Amino Acid Composition of Sow Milk

Milk protein fractionation studies showed no significant differences due to treatment (Table 8). However, amounts of casein, alpha and gamma globulins were lower for the low-low treatment. The beta globulin level was highest for the same treatment while lactalbumin was highest for the high-high treatment. Bourne (1969) separated the whey (albumin and globulin) of sows' milk and the results reported here are in agreement with his data. Morgan and Lecce (1964) studied the electrophoretic pattern of sows's milk. These workers reported that sow milk protein contained 40-50% casein. In the present study, 30-35% of the milk protein is casein. This lower value is due in part to differences

Table 8. Mean Composition of Milk Protein on the 21st Day of Lactation - Experiment 1

Protein Level in a) Gestation (%)	High (12.5)		Low (10.6)	
b) Lactation (%)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)
No. of samples used for analysis	6[1]	7[1]	6[1]	6[1]
Casein, %	1.74±0.13[2]	1.63±0.13	1.62±0.13	1.17±0.13
Alpha globulin, %	0.44±0.01	0.44±0.01	0.42±0.01	0.36±0.01
Beta globulin, %	1.18±0.09	1.13±0.08	1.11±0.09	1.42±0.09
Gamma globulin, %	0.47±0.02	0.52±0.02	0.46±0.02	0.39±0.02
Lactalbumin, %	2.01±0.18	1.66±0.18	1.53±0.18	1.67±0.18

[1]Only a limited number of milk samples were analyzed because of coagulation.

[2]Mean ± standard error

in techniques ie. the former used a high speed centrifugation (20,000 x g) while the gel electrophoretic technique was used in this study. The electrophoretic pattern of cow's milk reported in the literature indicated that 80% of the total milk protein is casein with whey protein making up the remainder. The data of this study indicate that sows' milk is more similar to human milk (50% casein and 50% whey protein) than to cow's milk

The amino acid composition of milk showed a specific pattern with six out of the nine essential amino acids and all the nonessential amino acids being lower in the milk of the low-low treatment group (Table 9). Due to partial oxidation of cystine and methionine during acid hydrolysis, the cystine and methionine values may be questioned. The arginine level was significantly higher ($P<0.05$) for the gestation high protein treatment. Methionine, cystine, aspartic acid and proline showed a significant ($P<0.05$) gestation x lactation interaction (Appendix Tables 10-17). When the amino acid concentrations were converted to a 16 g nitrogen base (per 100 g protein) the data were similar to the levels reported by Beacom and Bowland (1951) in spite of different methods used for hydrolysis and estimation of amino acid content (Table 10). The methionine content of sows' milk is similar to that of human milk reported by Morrison (1952).

Table 9. Amino Acid Content of Sow Milk (mg / 100 ml) for Three Reproductive Cycles* - Experiment 1

Protein Level in a) Gestation (%)	High (12.5)		Low (10.6)	
b) Lactation (%)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)
No. of samples	6[1]	7	5	6
Essential amino acids				
Arginine	0.21±0.02[a2]	0.23±0.02[a]	0.17±0.02[b]	0.16±0.02[b]
Histidine	0.11±0.01	0.12±0.01	0.11±0.01	0.10±0.01
Isoleucine	0.19±0.02	0.18±0.02	0.19±0.02	0.15±0.01
Leucine	0.40±0.03	0.40±0.03	0.41±0.03	0.33±0.03
Lysine	0.34±0.03	0.32±0.03	0.31±0.02	0.27±0.02
Methionine	0.08±0.00	0.08±0.00	0.07±0.00	0.09±0.00
Phenylalanine	0.18±0.02	0.19±0.02	0.19±0.01	0.16±0.01
Threonine	0.20±0.02	0.19±0.02	0.20±0.02	0.15±0.01
Valine	0.22±0.00	0.22±0.00	0.24±0.00	0.19±0.01

- Continued -

Table 9. Continued

Protein Level in a) Gestation (%)	High (12.5)		Low (10.6)	
b) Lactation (%)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)
Nonessential amino acids				
Alanine	0.16±0.01	0.15±0.01	0.16±0.01	0.14±0.01
Aspartic acid	0.40±0.02	0.43±0.01	0.42±0.03	0.34±0.02
Cystine	0.03±0.00	0.04±0.00	0.04±0.00	0.03±0.00
Glutamic acid	1.11±0.09	1.23±0.09	1.09±0.09	1.01±0.09
Glycine	0.16±0.01	0.17±0.01	0.16±0.01	0.14±0.01
Proline	0.51±0.04	0.58±0.02	0.56±0.04	0.43±0.13
Serine	0.25±0.01	0.25±0.01	0.24±0.01	0.20±0.01
Tyrosine	0.19±0.02	0.19±0.02	0.20±0.02	0.16±0.01

*Means having different lower case superscripts differ significantly, $P<0.05$

[1] Only a limited number of milk samples were analyzed because of coagulation.

[2] Mean ± standard error

Table 10. Amino Acid Content of Sow Milk (g / 16 g Nitrogen) for Three Reproductive Cycles* - Experiment 1

Protein Level in a) Gestation (%)	High (12.5)		Low (10.6)		
b) Lactation (%)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)	Sow milk[1]
No. of samples	6	7	5	6	
Essential amino acids					
Arginine	4.27±0.54[2]	4.23±0.50	3.12±0.59	3.10±0.54	5.7[3]
Histidine	2.29±0.13	2.27±0.11	2.07±0.12	1.82±0.13	2.2
Isoleucine	3.60±0.22	3.31±0.20	3.51±0.24	2.91±0.20	4.2
Leucine	7.97±0.43	6.93±0.40	7.50±0.46	6.32±0.43	8.0
Lysine	6.86±0.37	5.88±0.34	5.76±0.39	5.15±0.37	7.4
Methionine	1.62±0.29	1.52±0.27	1.21±0.31	1.65±0.28	1.4
Phenylalanine	3.71±0.18	3.46±0.17	3.56±0.19	3.03±0.18	3.5
Threonine	3.99±0.17	3.57±0.16	3.62±0.18	2.87±0.17	3.5
Valine	4.43±0.25	4.08±0.23	4.56±0.27	3.67±0.23	5.0

- Continued -

Table 10. Continued

Protein Level in a) Gestation (%)	High (12.5)		Low (10.6)	
b) Lactation	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)
Nonessential amino acids				
Alanine	3.27±0.26	2.82±0.24	3.25±0.28	2.78±0.26
Aspartic acid	8.01±0.36	7.93±0.33	7.75±0.39	6.47±0.36
Cystine	0.61±0.02	0.68±0.02	0.81±0.02	0.54±0.02
Glutamic acid	22.49±1.20	22.60±1.10	20.43±1.30	19.13±1.20
Glycine	3.32±0.18	3.06±0.16	3.18±0.19	2.62±0.18
Proline	10.35±0.45	10.65±0.41	11.17±0.49	7.99±0.45
Serine	5.01±0.60	4.60±0.54	3.80±0.64	2.87±0.60
Tyrosine	3.90±0.22	3.55±0.20	3.69±0.24	3.12±0.20

*Means having different lower case superscripts differ significantly, $P<0.05$

[1] Beacom and Bowland (1951)

[2] Mean ± standard error

[3] Standard error was not reported.

Linzel et al. (1969), using a mammary perfusion technique, showed that all the essential and certain nonessential amino acids were not synthesized in sows' mammary tissue. Thus mammary tissue amino acid supply is regulated by the amino acids in blood, so that a poor quality of ration protein in gestation and / or lactation could influence the synthesis of milk protein. This is probably a primary cause of the low milk protein in the low-low ration treatment.

5. Body Composition

The total body water content estimated by the tritium dilution technique showed that there were no significant differences in body water content of sows due to ration treatments in any of the three periods shown in Table 11. However, the body water content was highest at zero day of lactation compared to 21 days of lactation or 14 days post weaning. There was a significant ($P < 0.01$) period difference in body water content between the three periods.

This high body water content during the first period could be due to an enlarged uterus, congested mammary tissue and a general increase of body water during gestation. At the 21st day of lactation, with the uterus involuted and mammary congestion relieved by suckling pigs, body water content was lower. Fourteen days after weaning, the sows were dry and, as a result any extra water stored during

Table 11. Mean Total Body Composition of Lactating Sows for Two Reproductive Cycles*
- Experiment 1

Protein Level in a) Gestation (%)	High (12.5)		Low (10.6)		
b) Lactation (%)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)	Period mean
No. of animals[1]	6	6	6	6	
Total body water, %					
Zero day of lactation	55.6±2.3	55.2±2.3	59.0±2.3	55.2±2.3	56.2±1.1^{A}
21 days of lactation	51.5±1.6	52.3±1.6	52.4±1.6	50.1±1.6	51.6±0.6^{B}
14 days post weaning	48.8±1.6	47.9±1.6	48.2±1.6	47.2±1.6	48.0±0.6^{C}
Total body fat, %[2]					
Zero day of lactation	23.3±3.2	23.9±3.2	18.6±3.2	23.8±3.2	22.4±1.5^{A}
21 days of lactation	28.9±1.8	28.0±1.8	27.7±1.8	30.8±1.8	28.9±0.9^{B}
14 days post weaning	32.7±1.8	33.9±1.8	33.4±1.8	34.1±1.8	33.6±0.9^{C}
Total body protein, %[3]					
Zero day of lactation	17.5±0.7	17.4±0.7	18.6±0.7	17.4±0.7	17.8±0.4^{A}
21 days of lactation	16.3±0.4	16.5±0.4	16.5±0.4	15.8±0.4	16.3±0.2^{B}
14 days post weaning	15.4±0.4	15.1±0.4	15.2±0.4	14.9±0.4	15.2±0.2^{C}

- Continued -

Table 11. Continued

Protein Level in a) Gestation (%)	High (12.5)		Low (10.6)		
b) Lactation (%)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)	Period mean
Total body mineral, %[4]					
Zero day of lactation	3.6±0.1	3.5±0.1	3.8±0.1	3.5±0.1	3.6 ± 0.1^{A}
21 days of lactation	3.3±0.1	3.3±0.1	3.4±0.1	3.2±0.1	3.3 ± 0.0^{B}
14 days post weaning	3.1±0.1	3.1±0.1	3.1±0.1	3.0±0.1	3.1 ± 0.0^{C}

[*] Means having different upper case superscripts differ significantly, $P<0.01$

[1] Sixteen first litter sows and eight second litter sows were used in this study.

[2] Total body fat, % $= 100 \times \left[1 - \frac{\text{total body water \%}}{\text{water in fat-free body \% (72.5\%)}}\right]$

[3] Body protein, % $= \left[100 - (\text{total body water \%} + \text{total body fat \%})\right] \times 83.1$

[4] Body mineral, % $= \left[100 - (\text{total body water \%} + \text{total body fat \%})\right] \times 16.9$

pregnancy or lactation was lost. To date, total body water data have been available for pigs up to market weights with no reports regarding the total body composition of sows during lactation. Hansard (1964), using the tritium dilution technique reported the body water content of pigs (90 kg) as 49%. The results reported in this study for dry sows ranged from 47-49% being close to those reported in the literature for market pigs. As mentioned in the review of literature, tritium overestimates body water by 2-3%. If a correction was made for this overestimation the true body water in this study would be 45-47%.

Body fat, protein and minerals were calculated using the body water data reported here (Clawson _et al_. 1955). These results indicated that body fat is negatively correlated to body water content so that body fat was lowest at zero day of lactation and that body protein and minerals were positively correlated with body water and were highest at zero day of lactation and decreased as the body water declined.

Unpublished data from our laboratory (Stothers 1967) showed a negative nitrogen balance and loss of body weight immediately after weaning. This is consistent with the loss of body water and the loss of body protein just noted. During lactation, on the average, there were no large differences in feed consumption, milk produced or number of pigs weaned, thus eliminating some of the possible differences in body composition due to rations. When lactation was abruptly terminated at the peak of milk production, milk already produced and nutrients stored in the mammary tissue for milk synthesis would be surplus. The animals would use these extra nutrients for other body purposes or excrete them. Lodge (1959) noted an additional excretory phase in sows immediately after weaning with the loss of excess weight accumulated during gestation and lactation. Thus, the decrease in body protein estimated for the post weaning period, the negative nitrogen balance and loss of weight noted in the earlier study are consistent with the above observation.

6. First Reproductive Cycle Versus Second and Third Cycles

Gilts, which are usually referred to as sows after their first farrowing, are still growing animals. Thus, they usually gain more weight in pregnancy than mature sows. At breeding time the reproductive tract of gilts is not fully developed so that with the first farrowing fewer pigs are born than to mature sows. In addition, fewer and usually lighter pigs are weaned from the first litter than from later litters. This is taken as an indication of lower milk production for the first litter due to inadequate development of the mammary system. The data presented in Table 12 are consistent with the above observations.

Table 12. Mean Comparison of Sows' Reproductive Performances in First Versus Second and Third Reproductive Cycles - Experiment 1 *

	First Cycle	Second and Third Cycles
No. of animals[1]	16	27
Gestation wt. gain, kg	60.8±10.2[2]	54.9± 7.9
Sow farrowing wt., kg	172.8± 6.2[a]	203.7±10.3[b]
No. of pigs born	10.6± 0.7	11.7± 0.5
Birth wt., kg	1.4± 0.1	1.4± 0.1
No. of pigs weaned	8.5± 0.5	9.2± 0.4
Weaning wt. gain of pigs, kg	3.4± 0.2	3.2± 0.2
Feed intake, kg	4.1± 0.2	5.1± 0.1
Milk yield, kg	5.5± 0.8[A]	7.1± 0.6[B]
Milk protein, %	5.1± 0.1[a]	5.4± 0.1[b]
3 wk. sow wt. loss, kg[3]	-9.3± 3.1	-9.0± 1.7
Nitrogen retention, g	-3.2± 5.2	-6.7± 3.5
Body water, %		
No. of animals	16	8
Zero day of lactation	56.2± 1.1	- -
21 days of lactation	53.1± 0.8[A]	48.5± 1.1[B]
14 days post weaning	49.7± 0.8[A]	44.6± 1.1[B]

*Means having different upper case superscripts differ significantly, P<0.01.
Means having different lower case superscripts differ signigicantly, P<0.05.

[1] See footnote 1, Table 5.

[2] Mean ± standard error

[3] Data from Replicate 1 were not included in the first cycle due to restricted feeding in lactation.

B. EXPERIMENT II

1. Gestation and Farrowing Performance of Gilts and Sows

Table 13 shows the combined weight gain of pregnant gilts and sows over two reproductive cycles. There were no significant differences in weight gain between periods. The group receiving added lysine showed a higher weight gain than those receiving the control ration in the first and third periods. The control group showed a slightly higher gain during the second and fourth periods. The total and daily weight gain during gestation were higher for gilts and sows fed the lysine supplemented ration. The results of Experiment 1 and of Rippel et al. (1965d) are quite comparable to the results of Experiment 11.

Sow weight loss at farrowing was not influenced by the level of lysine in the gestation ration. The number of pigs born was similar but the number of pigs born alive was slightly higher for the sows fed the control ration (Table 14). The birth weight of all the pigs and the birth weight of the live pigs were simialr for the control and lysine supplemented groups. However, the control ration fed sows farrowed slightly heavier pigs than sows fed a ration supplemented with lysine. Rippel et al. (1965d) reported a similar finding with a cereal ration supplemented with 0.3% lysine. Using a barley based ration plus a 1% lysine and methionine

Table 13. Mean, Total and Daily Weight Gain (Kg) of Pregnant Gilts and Sows for Two Reproductive Cycles - Experiment 11

Protein Level in Gestation (%)	Control (10.6)	Control + Lysine (10.9)
No. of animals[1]	15	13
Initial weight[2]	148.7 ±6.8[3]	140.7 ±7.2
Period weight gain		
First	10.4 ±2.1	13.4 ±1.5
Second	14.2 ±1.4	13.1 ±1.7
Third	11.5 ±1.5	13.2 ±1.5
Fourth	11.9 ±1.7	10.4 ±1.7
Total weight gain	48.0 ±5.5	50.1 ±5.8
Av. daily wt. gain	0.44±0.02	0.46±0.02

[1] Four sows were removed from the experiment after the first lactation due to reproductive failure.

[2] Initially ten gilts were group fed and penned with boars for one month. Due to lack of data the initial weights and first period weight gain were for 7 control-fed animals and 11 control + lysine-fed animals.

[3] Mean ± standard error

Table 14. Mean Farrowing Performance of Sows and Litters for Two Reproductive Cycles - Experiment 11

Protein Level in Gestation (%)	Control (10.6)	Control + Lysine (10.9)
No. of litters	15[1]	13
Wt. loss after farrowing, kg	15.9 ±0.6[2]	15.3 ±0.6
No. of pigs born	9.9 ±0.4	9.7 ±0.4
No. born alive	9.2 ±0.4	8.3 ±0.4
Birth wt., kg	1.35±0.05	1.30±0.05
Birth wt. of live pigs, kg	1.38±0.05	1.33±0.05

[1]See footnote 1, Table 13.

[2]Mean ± standard error

mixture from the 90th day postcoitum,Ting (1967) found no difference in farrowing performance between the control and supplemented groups.

2. Lactation Performance

The number of pigs weaned by sows which received lysine supplementation was slightly lower than for the control group (Table 15). The farrowing period which started on the 29th of May, 1969, was completed on the 28th of August, 1969. During this period 42 sows farrowed and their litters were weaned in the same barn. This created a favorable environment for a scours outbreak during the latter part of the farrowing season. Since most of the control animals farrowed in June and July, 1969 a greater proportion of the lysine fed group which farrowed at the end of July and August, 1969 had litters which were more susceptible to the scours outbreak in the barn. Hence, smaller litters containing pigs of lighter weight were weaned. The cumulative weight gain of pigs showed no difference between treatments during the first week of lactation. However, during the second week, the pigs from the control group gained significantly ($P<0.05$) more weight. The lower weight gain of pigs from the lysine supplemented group during the second week was primarily due to scours. This difference in weight still remained at the end of the third week with a slight additional increase in the difference

Table 15. Means for Three Week Lactation Performance of Litters from Two Reproductive Cycles* - Experiment 11

Protein Level in a) Gestation (%)	Control (10.6)	Control + Lysine (10.9)
b) Lactation (%)	Control (12.8)	Control + Lysine (12.8)
No. of litters[1]	12	10
No. of pigs weaned / litter	8.1 ±0.4[2]	7.4 ±0.4
Pigs' cumulative weekly wt. gain, kg		
First week	1.01±0.07	1.13±0.07
Second week	2.27±0.12[a]	1.90±0.12[b]
Third week	3.30±0.17[A]	2.89±0.17[B]
3 wk. cumulative litter weaning wt. gain, kg	26.5 ±1.9[a]	21.3 ±1.9[b]

*Means having different upper case superscripts differ significantly, $P<0.01$.
Means having different lower case superscripts differ significantly, $P<0.05$.

[1] Data from six sows from the first lactation were not included due to a scours outbreak. In addition, four sows were removed from the experiment after the first lactation due to reproductive failure.

[2] Mean ± standard error

during the third week. Due to differences already noted in litter size weaned and weekly weight gain, the litter weight gain was significantly ($P<0.05$) higher for the control group. This result is in contrast to the results of O'Grady (1967) where an increased lysine content of the lactation ration increased the pig weight gain. However, the lysine level of the control and lysine supplemented rations in this test were 0.61 and 0.72% respectively compared to 0.39 and 0.52% in O'Grady's (1967) rations. Thus the lowest lysine level reported here, is higher than the highest lysine level reported by O'Grady (1967). As reported in Experiment 1, the low protein ration contained 0.34% lysine compared to 0.72% in the high protein lactation ration with the effects on pig weight gain similar to O'Grady's (1967).

However, O'Grady (1967), instead of supplementing lysine, adjusted the fish meal content of the ration so that the higher weight gain noted may be due to a better overall balance of amino acids in the ration for optimum milk protein synthesis. Based on all these data, the optimum lysine level in the lactation ration seems to be in the range of 0.50 to 0.60% of the ration. Future experiments should be planned to study this range as well as its relationship to other amino acid requirements.

There was no significant difference in feed intake of sows although the lysine supplemented group ate 0.58 kg per day

Table 16. Means for Three Week Lactation Performance of Sows from Two Reproductive Cycles - Experiment 11

Protein Level in		
a) Gestation (%)	Control (10.6)	Control + Lysine (10.9)
b) Lactation (%)	Control (12.8)	Control + Lysine (12.8)
No. of sows[1]	12	10
Feed intake, kg / day	4.58±0.70[2]	4.00±0.76
Milk yield, kg / day[3]	6.06±0.34	5.48±0.34
Milk protein, %[4]	5.51±0.18	5.47±0.18
Sow weekly wt. loss, kg		
First week	-4.80±1.40	-4.51±1.40
Second week	-8.00±1.60	-7.92±1.60
Third week	-11.30±2.24	-11.59±2.24

[1] See footnote 1, Table 15

[2] Mean ± standard error

[3] Milk yield was estimated between the 17th and 20th days of lactation.

[4] Milk samples were collected on the 21st day of lactation.

less, probably due to a lower number of pigs weaned per litter (Table 16). There was no significant difference between the control and lysine supplemented groups in milk yield or CP content but sows receiving the control ration produced slightly more milk containing slightly more protein. This was reflected in the greater number and higher weaning weight of pigs reared by these sows. Cumulative weight losses by the sows at the end of each week did not show any significant differences. The live weight changes of the sows that completed the two reproductive cycles are shown in Figure 2. The gilts and sows fed the lysine supplemented ration gained more in gestation, although the lactation losses were similar.

3. Nitrogen Balance

There were no significant differences between groups in daily feed intake, daily nitrogen intake or apparent nitrogen absorption (Table 17). However, the lysine supplemented treatment had a slightly higher nitrogen absorption and therefore, a higher apparent digestibility (82%). The amount of nitrogen excreted in the urine was 5 g higher for the control group and because of greater milk production, nitrogen excretion in the milk was higher for the control group. The net effect of these data was that nitrogen retention was higher for the lysine supplemented group, with sows fed the control ration being in negative nitrogen balance.

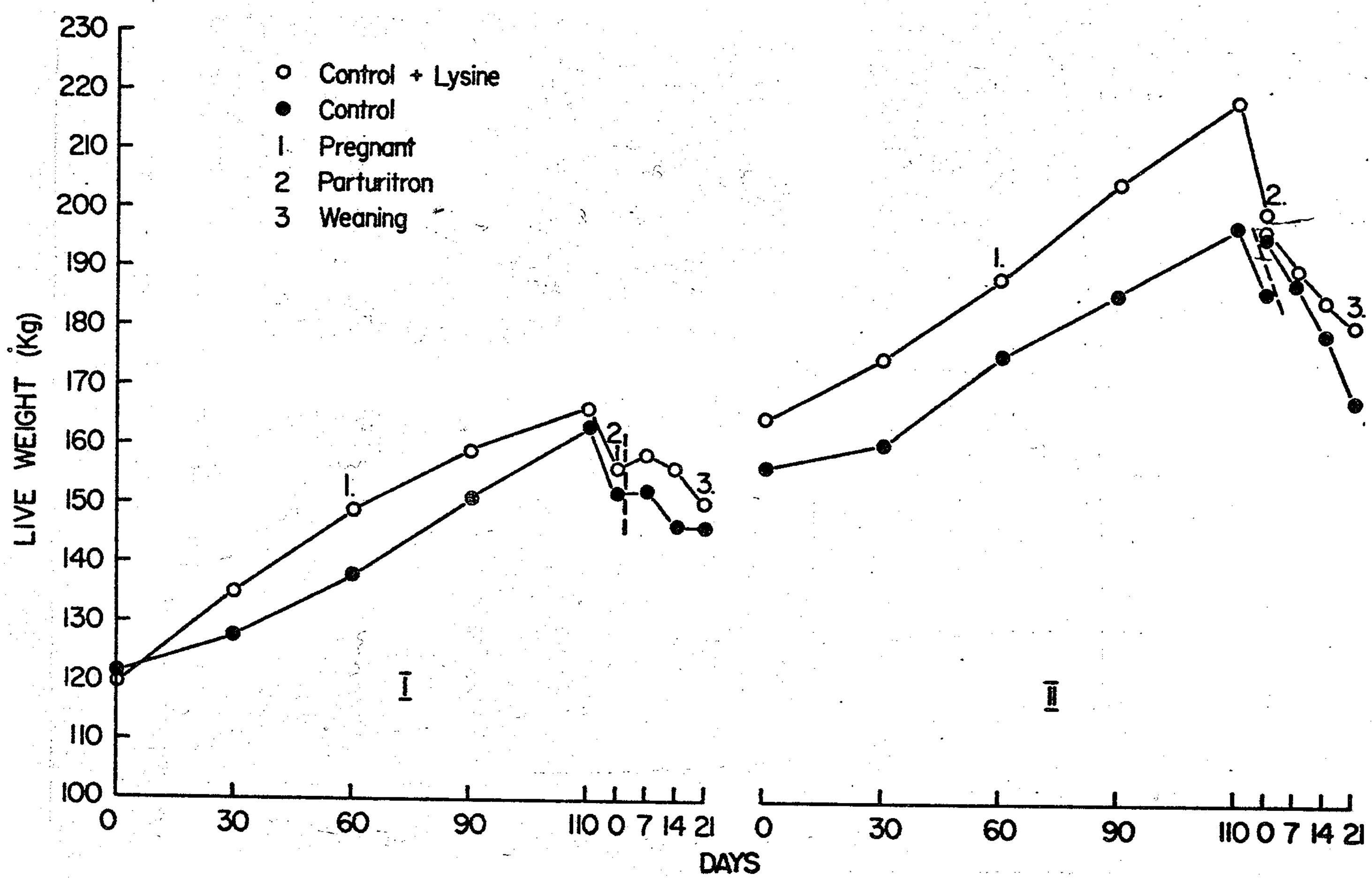

Figure 2. Live Weight Changes of Gilts and Sows in Two Reproductive Cycles - Experiment 11

Table 17. Means of Daily Nitrogen Balance Trial Data from 17th-20th Days of Lactation - Experiment 11

Protein Level in a) Gestation (%)	Control (10.6)	Control + Lysine (10.9)
b) Lactation (%)	Control (12.8)	Control + Lysine (12.8)
No. of animals[1]	12	10
Feed intake, kg	4.31±0.29[2]	4.17±0.29
Nitrogen intake, g	85.61±6.20	87.70±6.20
Apparent nitrogen absorbed, g	66.17±5.00	71.77±5.00
Nitrogen in urine, g	20.88±2.16	15.88±2.16
Nitrogen in milk, g	53.01±3.98	47.82±3.98
Nitrogen retained, g	-5.38±5.50	10.41±5.50

[1] See footnote 1, Table 15.

[2] Mean ± standard error

However, the sows fed the control ration weaned more and heavier pigs, the ultimate goal of efficient swine production.

4. Amino Acid Composition of Sow Milk

Sow milk was only analyzed for basic amino acids because of the primary interest on the effect of lysine supplementation of the control ration (Table 18). Almost identical amounts of arginine, histidine and lysine were noted for the control and lysine supplemented groups so that no significant differences were noted. To date, no one has published information on effects of amino acid supplementation on milk composition. Therefore, the data in this experiment need expansion through further research, including amino acid imbalances and possible toxicities.

5. First Reproductive Cycle Versus Second Cycle

The data from the first reproductive cycle were impaired by baby pig scours. Gilts gained more weight in gestation but the farrowing and lactation performance were inferior to that of sows from the second cycle. In general, the usual differences in performance of gilts and sows apply to this experiment and were also mentioned in Experiment 1 (Table 19).

Table 18. Basic Amino Acid Content of Sow Milk (mg / 100ml; g / 16 g Nitrogen) for Two Reproductive Cycles - Experiment 11

Protein Level in a) Gestation (%)	Control (10.6)	Control + Lysine (10.9)
b) Lactation (%)	Control (12.8)	Control + Lysine (12.8)
No. of samples[1]	3	3
Arginine, mg/100 ml	0.25±0.02[2]	0.24±0.02
Histidine, mg/100 ml	0.13±0.01	0.14±0.01
Lysine, mg/100 ml	0.39±0.02	0.39±0.02
Arginine, g/16 g Nitrogen	4.5 ±0.4	4.4 ±0.3
Histidine, g/16 g Nitrogen	2.3 ±0.2	2.6 ±0.2
Lysine, g/16 g Nitrogen	7.0 ±0.4	7.1 ±0.3

[1] Only six milk samples were analyzed due to limited facilities.

[2] Mean ± standard error

Table 19. Mean Comparison of Sows' Reproductive Performances in First Versus Second Reproductive Cycle* - Experiment 11

	First Cycle	Second Cycle
No. of animals[1]	10	12
Gestation wt. gain, kg	51.7±3.6[2]	45.1±3.3
Sow farrowing wt., kg	153.9±4.8	192.9±5.6
No. of pigs born	9.6±0.5	10.2±0.5
Birth wt., kg	1.3±0.1	1.4±0.1
No. of pigs weaned	6.4±0.6[A]	8.8±0.4[B]
Weaning wt. gain of pigs, kg	2.5±0.2[A]	3.4±0.2[B]
Feed intake, kg	3.5±0.4[a]	4.9±0.3[b]
Milk yield, kg	4.4±0.4[A]	6.9±0.3[B]
Milk protein, %	5.5±0.2	5.5±0.2
3 wk. sow wt. loss, kg	-9.1±2.4	-13.4±2.2
Nitrogen retention, g	1.0±5.6	3.4±5.6

*Means having different upper case superscripts differ significantly, $P<0.01$.
Means having different lower case superscripts differ significantly, $P<0.05$.

[1] See footnote 1, Table 15.

[2] Mean ± standard error

6. Plasma Amino Acids in Gestation and Lactation

Plasma amino acid profiles are shown in Table 20, and Figures 3 and 4.

All animals were fasted for 18 hours after which blood samples were collected while postprandial blood samples were collected 3.5 hours after feeding. For animals fed both rations during pregnancy, postprandial levels of phenylalanine and threonine were significantly ($P < 0.05$) higher than fasting levels. All plasma amino acids were higher in postprandial plasma with the following exceptions, (a) for the control fed animals, histidine and aspartic acid levels were lower during pregnancy and aspartic acid and glycine levels were lower during lactation, and (b) for the lysine supplemented animals, threonine, phenylalanine and glutamic acid levels were lower in plasma during lactation.

The addition of lysine to the control rations, both in pregnancy and in lactation resulted in some changes in the plasma amino acid pattern. As expected, the postprandial lysine level was significantly ($P < 0.05$) higher for the lysine supplemented treatments in gestation; in lactation, although the lysine level was higher for the lysine fed animals, it was not significantly different from the control fed animals. The levels of isoleucine, leucine, threonine and proline were significantly ($P < 0.05$) different for the lysine supplemented

Table 20. Concentration of Amino Acids (umoles / litre) in Plasma of Sows During Gestation (G) and Lactation (L) - Experiment 11*

Protein Level in					
a) Gestation		Control (10.6)		Control + Lysine (10.9)	
b) Lactation		Control (12.8)		Control + Lysine (12.8)	
Period		Fasting	Fed	Fasting	Fed
No. of samples					
G		6[1]	6	4	4
L		5	5	3	3
Essential amino acids					
Histidine					
G		121.86± 9.75[2]	117.23± 9.75	115.00±11.94	126.60±11.94
L		139.28±17.90	153.60±17.90	133.30±20.11	146.66±20.11
Isoleucine					
G	B[3]	116.20± 5.48	119.66± 5.48	92.55± 6.71	94.80± 6.71
L		93.62±13.98	100.24±13.98	106.00±18.05	109.18±18.05
Leucine					
G	b	198.00±10.84	213.43±10.84	174.20±13.28	184.80±13.28
L		153.20±35.01	167.04±35.01	191.50±45.20	217.66±45.20
Lysine					
G	b	141.80±21.23	150.60±21.23	162.43±26.00	262.30±26.00
L		199.44±42.80	225.60±42.80	193.73±55.26	272.87±55.26

-Continued -

Table 20. Continued

Protein Level in a) Gestation		Control (10.6)		Control + Lysine (10.9)	
b) Lactation		Control (12.8)		Control + Lysine (12.8)	
Period		Fasting	Fed	Fasting	Fed
Methionine					
G		43.92± 5.93	43.89± 5.93	38.35± 7.17	47.63± 7.27
L		38.00± 5.71	42.32± 5.71	35.46± 7.39	42.19± 7.39
Phenylalanine					
G	a	96.67± 7.45	114.66± 7.45	82.10± 9.10	103.90± 9.13
L		92.72±26.73	149.76±26.73	121.47±34.51	111.38±34.51
Threonine					
G	aB	192.80± 22.23	286.76±22.23	151.70±27.22	166.80±27.22
L		185.68±26.35	205.92±26.35	174.64±34.02	173.33±34.02
Valine					
G		274.87±20.29	317.75±20.29	265.00±25.34	247.20±25.34
L		281.84±41.53	286.40±41.53	291.00±53.61	346.76±53.76

- Continued -

Table 20. Continued

Protein Level in				
a) Gestation	Control (10.6)		Control + Lysine (10.9)	
b) Lactation	Control (12.8)		Control + Lysine (12.8)	
Period	Fasting	Fed	Fasting	Fed
Nonessential amino acids				
Alanine				
G	665.86±59.90	762.43±59.90	646.75±72.34	678.20±72.34
L	452.53±80.00	760.37±80.00	690.08±83.17	735.88±83.17
Aspartic acid				
G	41.96± 7.22	33.34± 7.22	30.84± 3.52	33.04± 3.52
L	32.60± 1.90	28.30± 1.90	34.86± 5.01	54.08± 5.01
Cystine				
G	7.30± 1.75	8.52± 1.75	6.46± 1.84	7.14± 1.84
L	26.07± 5.46	17.57± 5.46	13.60± 4.49	20.92± 4.49
Glutamic acid				
G b	239.66±17.22	258.97±17.22	318.40±52.62	331.30±52.62
L	284.40±50.80	199.74±50.80	321.60±104.89	349.46±104.89
Glycine				
G	882.86±59.45	1,034.68±59.45	824.50±102.64	775.50±102.64
L	775.60±153.95	779.04±153.95	536.12±141.83	719.08±141.83

- Continued -

Table 20. Continued

Protein Level in					
a) Gestation		Control (10.6)		Control + Lysine (10.9)	
b) Lactation		Control (12.8)		Control + Lysine (12.8)	
Period		Fasting	Fed	Fasting	Fed
Proline					
G	a	215.73±24.04	396.90±24.04	199.96±10.08	259.70±10.08
L	a	151.07±17.75	348.46±17.75	200.80±33.50	247.04±33.50
Tyrosine					
G		84.67±11.57	119.73±11.57	84.80±12.04	100.10±12.04
L		97.07±27.09	114.38±27.09	92.28±23.03	114.32±23.03
Metabolites of urea cycle					
Citrulline					
G	b	110.92±11.20	133.20±11.20	72.10±15.80	90.50±15.80
L		241.80±61.80	91.20±61.80	125.20±48.80	258.60±48.80
Ornithine					
G		110.91±22.50	156.05±22.50	139.90±30.40	167.60±30.40
L		89.10±25.60	117.50±25.60	129.60±42.40	128.50±42.50
Urea					
G	b	5,214.00±485.20	5,936.00±485.20	3,340.00±480.70	3,937.00±480.60
L		5,053.00±1,078.00	4,945.00±1,078.00	3,361.30±603.80	5,911.20±603.80

- Continued -

Table 20. Continued

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[1]Only a limited number of blood samples were selected at random because of lack of facilities.

[2]Mean ± standard error

[3]The following refers to:

"a" Overall mean for fasting levels differs significantly from fed levels, $P < 0.05$.

"A" Overall mean for fasting levels differs significantly from fed levels, $P < 0.01$.

"b" Overall mean for control levels differs significantly from control + lysine level, $P < 0.05$.

"B" Overall mean for control levels differs significantly from control + lysine level, $P < 0.01$.

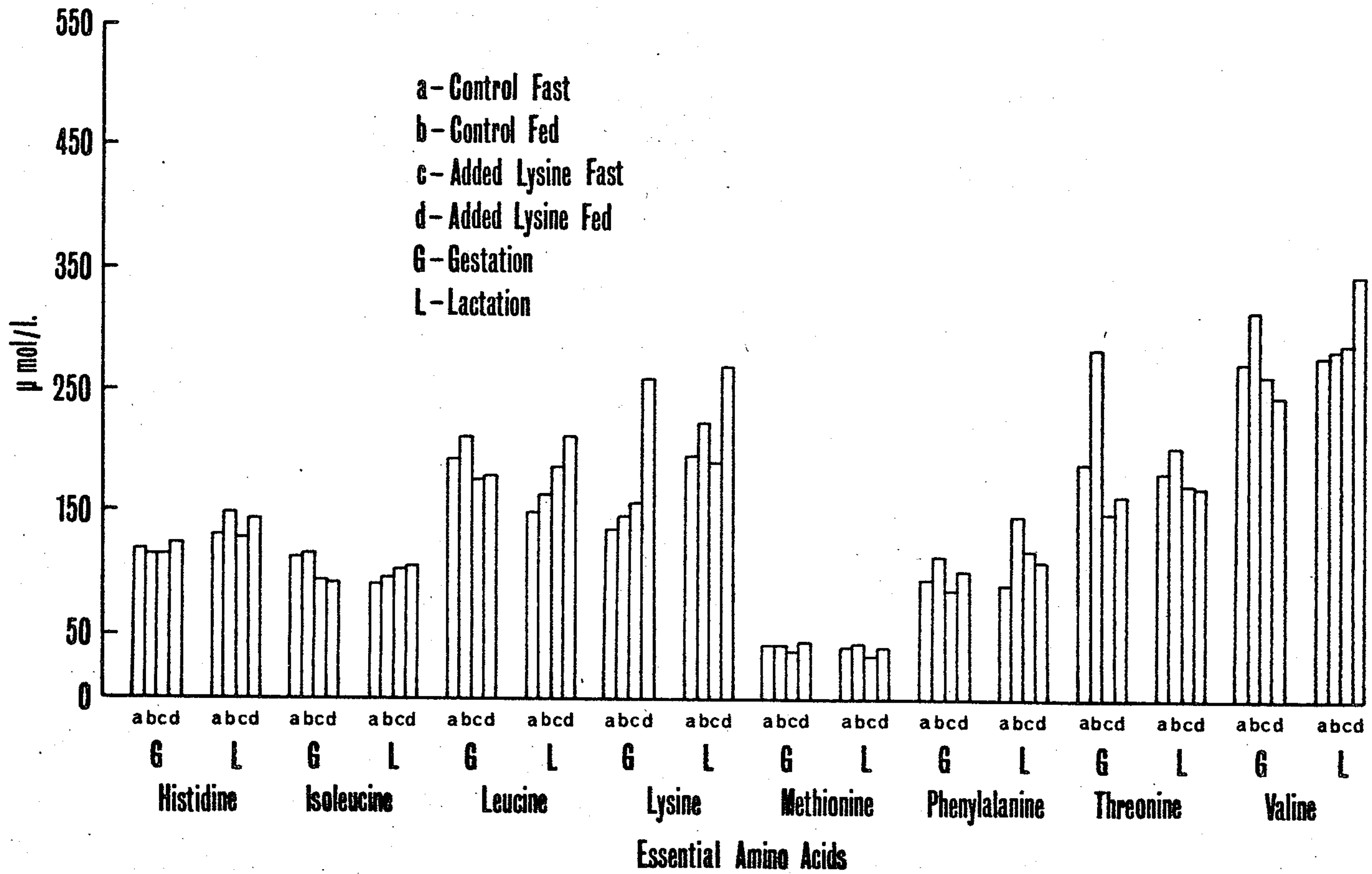

Figure 3. Essential Amino Acid Concentration in the Blood Plasma of Gilts and Sows in the First Reproductive Cycle - Experiment 11

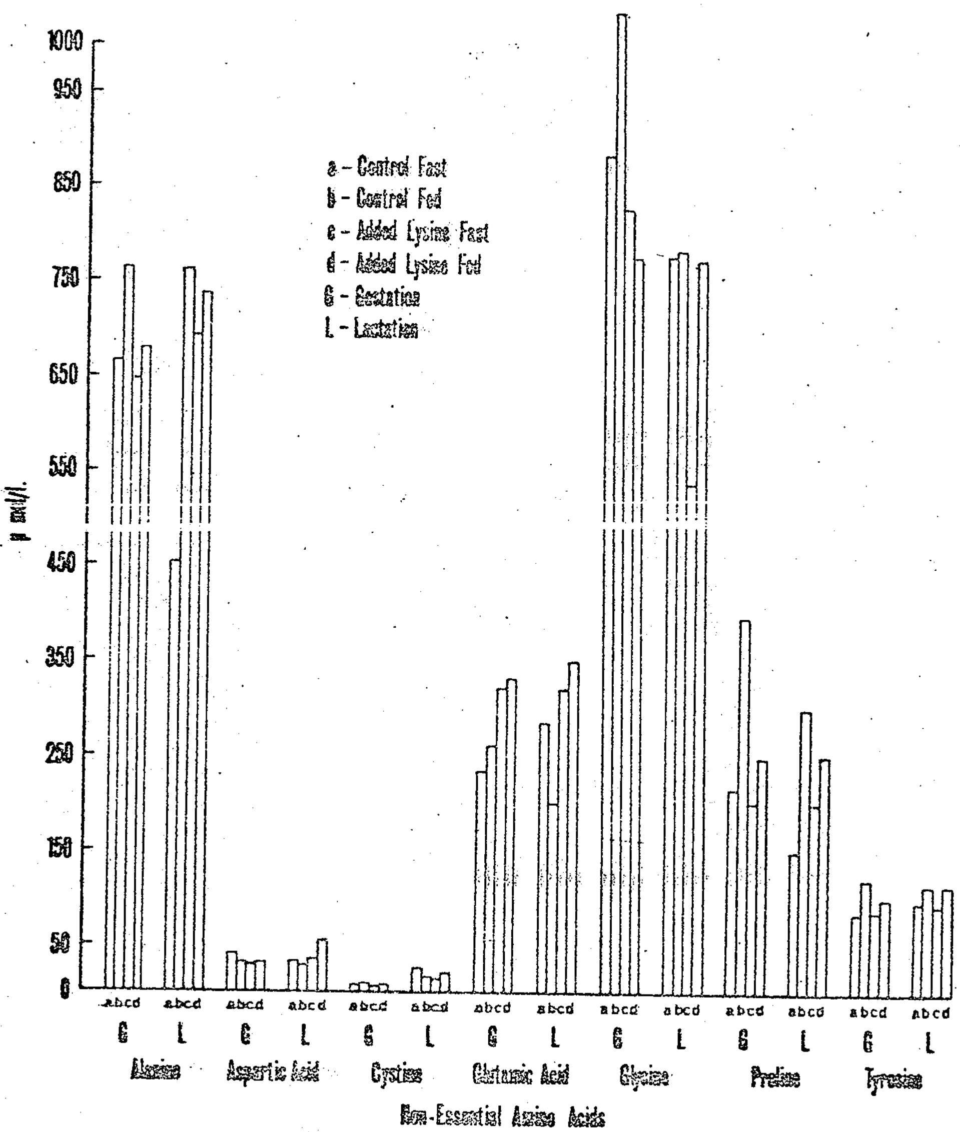

Figure 4. Nonessential Amino Amino Concentration in the Blood Plasma of Gilts and Sows in the First Reproductive Cycle - Experiment 11

group compared to the control ration fed animals during gestation. Blood urea and citrulline levels were significantly ($P<0.05$) higher for control fed animals during gestation.

Using male growing rats, Morrison et al. (1961) found that the plasma lysine value rose rapidly in response to added dietary lysine and reached a maximum at a dietary lysine level of 1%. This amount of dietary lysine was about 0.2% greater than that necessary for maximum growth. They also found that plasma threonine levels showed a reciprocal relationship with that of lysine. Morrison et al. (1961) concluded that plasma lysine and threonine levels may provide a sensitive indication of adequacy of dietary lysine. In the present study addition of lysine to a control ration during pregnancy and lactation decreased the threonine level in the plasma. This was significant ($P<0.01$) during pregnancy due to the lower lysine content in the control ration. Thus the results in this study are consistent with Morrison et al. (1961).

The gestation blood samples were collected between the 90 and 98th day of gestation whereas the lactation blood samples were collected on the 21st day of lactation. Due to the differences in ration protein and lysine levels statistical comparisons of gestation and lactation plasma amino acid levels were not possible. However, the plasma levels of histidine, lysine, phenylalanine and tyrosine were higher in lactation when compared with gestation probably due to a higher protein, lysine and feed intake (4.79 versus 2.21 kg) during lactation.

Thus the results of the present study are in contrast to the results obtained by Lucas et al. (1969). These researchers observed higher plasma levels for lysine, methionine, and threonine in gestation compared to lactation. The contrasting results may be due mainly to differences in blood sampling time. Nasset and Ju (1970) observed that plasma amino acids levelled off at four hours postprandial. Hence, in the present study, when postprandial blood was collected both in gestation and lactation the plasma amino acids should have levelled off. The plasma amino acid levels obtained by Lucas et al. (1969) would have levelled off only in gestation since lactation blood samples were collected one hour postprandial.

In addition, the amino acid composition of the ration of Lucas et al. (1969) remained constant both in gestation and lactation in spite of increased feed consumption during a two week lactation period. In the present study, the gestation rations were barley based rations whereas during the three week lactation period barley-soybean rations were fed. At blood sampling time in lactation, the sows of Lucas et al. (1969) were consuming about one kg more of feed/day than the sows of this study. Therefore, differences in plasma amino acids seen in this experiment in comparison with the data of Lucas et al. (1969) may also be due to (a) differences in protein quality of the ration and (b) differences in levels of feed consumption and / or length of lactation period.

C. EXPERIMENT 1 VERSUS EXPERIMENT 11

The amino acid composition of the gestation and lactation rations fed in Experiments 1 and 11 are given in Appendix Tables 1 and 25.

Sow gestation weight gain, feed consumption during lactation, milk yield, farrowing and lactation performance of litters were superior in Experiment 1. Due to larger and heavier litters, the sows in Experiment 1 were in negative nitrogen balance at the end of 21 days of lactation. All the gestation rations in Experiment 1 contained 10% alfalfa meal while none was used in Experiment 11. The higher number of pigs born in Experiment 1 may be due to this difference in ration treatment. Palmer (1962) reported an increased ovulation rate and embryo survival when dehydrated cereal grass was added to gestation rations.

In addition, the gestation rations of Experiment 11 were low in Vitamin A (approximately 180 I.U.). However, the lower weaning weight and fewer number of pigs weaned in Experiment 11 appears to be mainly due to a scours outbreak in Cycle 1. Weaning weights of pigs in Cycle 2, Experiment 11 were comparable to Cycles 2 and 3, Experiment 1. In summary, the results of these two experiments indicated that 10% CP during gestation followed by a 15% CP ration in lactation gave as good results as a 12-13% CP ration during gestation followed by 15% CP in lactation.

Even though litter weight gains of Experiment 11, Cycle 2 were comparable to some extent with Experiment 1, it is difficult to make a precise comparison. In Cycles 2 and 3, Experiment 1, 9.2 pigs / litter were weaned but only 8.8 pigs / litter were weaned in Cycle 2, Experiment 11. The addition of lysine to a barley-soybean lactation ration did not improve the lactation performance of sows or their litters.

D. FUTURE AREAS OF RESEARCH

The results of Experiment 1 have indicated that the CP requirement for lactating sows was between 10-15% of the ration. MacPherson et al. (1969) reported that a protein level above 14% in the lactation ration did not produce a beneficial effect in terms of litter weaning weight. Experiment 11 in this study further revealed that optimum litter performance might be obtained by feeding 12-13% CP in the lactation ration. In the future, various protein levels between 10 and 15% should be tested using a greater number of sows and natural-type rations. There are little published data available regarding amino acid requirements of the lactating sow. It is difficult to draw extensive conclusions from the results of Holden et al. (1968) due to the semi-purified rations used in their study where lysine levels in the rations were 0.43 to 1.11%. O'Grady (1967) also indicated that the lysine requirement of the lactating sow is between 0.39-0.51% of the ration. The results of Experiments 1 and 11 of this study would indicate the lysine requirement is between 0.34-0.60% for the lactating sow.

The present study also indicated that the first cycle lactation performance was affected by the quantity and quality of protein in the ration to a greater extent than subsequent lactations. Thus, when gilts were fed an all-cereal ration in gestation and in lactation, milk produced in Cycle 1 was low in casein, alpha and gamma globulins, lactalbumin and the following amino acids: arginine ($P < 0.05$), leucine, lysine, phenylalanine, threonine and valine. Further studies should be carried out on the effect of various amino acid supplementation on milk protein composition.

There is little information available on the plasma amino acid profile during various stages of lactation as affected by quality of the ration protein. Experiment 11 reported in this thesis indicated that both fasting and fed levels of plasma amino acids could help in assessing the amino acid needs of the lactating sow. Thus, when a barley based ration was fed in gestation the lysine level remained low in the plasma and the threonine level was higher. However, when lysine was supplemented in the gestation ration the plasma lysine level increased whereas the threonine level decreased. A similar response was seen in lactation, but this was not markedly observed, apparently due to the adequacy of lysine in the ration. Therefore, additional studies should be carried out testing the plasma amino acid profiles during various stages of lactation including the effect of quality of protein and various amino acid supplementation.

From a basic standpoint, using a mammary perfusion technique one could study the turnover rates of various amino acids in mammary tissue for milk protein synthesis. Turnover studies in conjunction with activities of certain enzymes in lactating sows' mammary tissue would also help in assessing the protein and amino acid requirements for lactation.

A carry over effect of the gestation protein level on lactation litter performance was noticed in Experiment 1. The quantity and quality of protein fed in gestation apparently affected the milk protein synthesis, thus influencing the litter weight gain. Since current information on gestation amino acid requirements is limited further research in this area is needed. Such research should be planned to assess the possible carry over effect so that lactation amino acid requirements could be better understood.

CONCLUSIONS

In Experiment 1, the effects of feeding two levels of protein in gestation and two levels of protein in lactation and their effect on sow gestation, farrowing, lactation performance, body composition, nitrogen retention, milk yield and milk protein composition were studied for three reproductive cycles.

Due to the loss of some sows in Replicate 11, data from only a limited number of sows were obtained. This was applicable to the second and third reproductive cycles.

The conclusions of Experiment 1 are:

(1). Feeding an all-cereal ration containing 227 g CP per day compared to 270 g CP per day from a cereal and soybean meal ration did not affect the gestation weight gain and farrowing performance of the sow.

(2). The pigs from sows fed a higher level of CP either in gestation (12% CP barley-soybean) or in lactation (15% CP barley-soybean) gained more compared with pigs from sows fed a low protein (10% CP cereal) in both periods.

(3). Sows fed a higher level of CP (15%) in lactation retained significantly ($P < 0.01$) more nitrogen and lost less weight at 3 weeks weaning.

(4). Almost identical quantities of milk were produced by the sows from all four treatments during the third week of lactation but the protein content of sows' milk was lower for the sows receiving low protein in both periods. The casein content of milk was lower for the low-low treatment. The higher level of protein either in gestation or in lactation influenced the following essential amino acid content of the milk: arginine, isoleucine, leucine, lysine, phenylalanine and valine.

(5). Total body water and body composition did not show any appreciable treatment difference. However, period means showed significant ($P < 0.01$) changes in body composition between the three periods.

In Experiment 11, 227 g CP from a barley based ration was fed as a control in gestation and 0.2% lysine was supplemented to the control ration. In lactation a control ration (12% CP barley-soybean) was fed to appetite with or without lysine supplementation. Lysine was supplemented at 0.2% of the ration.

The conclusions of Experiment 11 are:

(6). Gestation weight gain and farrowing performance did not show any significant difference between treatments.

(7). In lactation the pigs from sows fed the lysine supplemented ration gained significantly ($P < 0.01$) less when compared to sows fed the control ration at the end of 3 weeks weaning.

(8). Nitrogen retention was higher for the lysine supplemented group, but no difference in weight loss was observed between the treatments.

(9). There were no significant differences in milk yield, milk protein content or basic amino acid composition when lysine was supplemented.

(10). Plasma amino acid profiles showed a response to feeding. The 3 hours postprandial plasma amino acids were higher compared with the levels after 18 hours fasting. The plasma lysine level was increased with lysine supplementation whereas threonine levels decreased. These changes were only significant ($P < 0.05$) in gestation. However, plasma amino acid levels were generally higher in lactation than in gestation.

Appendix Table 1. Outline of Experimental Design - Experiment 1

	First Cycle[1]				Second and Third Cycles			
Protein Level in a) Gestation (%)	High (12.5)		Low (10.6)		High (12.5)		Low (10.6)	
b) Lactation (%)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)	High (15.7)	Low (10.8)
Replicate No. 1	2[2]	2	2	2	4	4	4	4
Replicate No. 2	2	2	2	2	4	1[3]	4	2[3]

[1] One cycle consists of a complete gestation-lactation period.

[2] Indicates the number of pigs in that treatment combination

[3] One sow from each of the high-low and low-low treatments died after the first lactation due to broken pelves. In the second lactation a third sow from the high-low treatments was removed because she was a repeat breeder.

Appendix Table 2. Amino Acid Composition (%) of Gestation and Lactation Rations - Experiment 1

Ration	Gestation		Lactation	
Protein (%)	High (12.5)	Low (10.6)	High (15.7)	Low (10.8)
Essential amino acids				
Arginine	0.64	0.61	0.94	0.50
Histidine	0.26	0.23	0.32	0.20
Isoleucine	0.56	0.50	0.72	0.35
Leucine	1.15	1.03	1.38	0.73
Lysine	0.54	0.45	0.72	0.34
Methionine	0.19	0.15	0.21	0.10
Phenylalanine	0.81	0.74	0.94	0.50
Threonine	0.54	0.27	0.59	0.33
Valine	0.73	0.68	0.87	0.48

- Continued -

Appendix Table 2. Continued

Ration	Gestation		Lactation	
Protein (%)	High (12.5)	Low (10.6)	High (15.7)	Low (10.8)
Nonessential amino acids				
Alanine	0.58	0.52	0.70	0.36
Aspartic acid	1.18	0.91	1.42	0.61
Cystine	0.13	0.09	0.16	0.10
Glutamic acid	4.51	4.42	4.94	3.27
Glycine	0.78	0.72	0.92	0.50
Proline	1.56	0.87	1.63	1.07
Serine	0.68	0.57	0.75	0.43
Tyrosine	0.51	0.47	0.59	0.30

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Appendix Table 3. Analysis of Variance - Experiment 1

Sources of Variation	df
Cycle	1
Gest[1]	1
Lact[1]	1
Rep[1]	1
Cycle x Gest	1
Cycle x Lact	1
Cycle x Rep	1
Gest x Lact	1
Gest x Rep	1
Lact x Rep	1
Cycle x Gest x Lact	1
Cycle x Gest x Rep	1
Cycle x Lact x Rep	1
Gest x Lact x Rep	1
Cycle x Gest x Lact x Rep	1
Error	27
Total	42

[1] Subsequently, the following abbreviations Gest, Lact and Rep will refer to gestation, lactation and replicate, respectively.

Note: All the analyses of variance are not shown in the subsequent tables. Only those analyses of variance which are significant for main effects and interactions are shown.

Appendix Table 4. Analysis of Variance of Three Week Cumulative Weight Gain of Pigs from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	0.614	1.00
Gest	1	0.091	-
Lact	1	3.108	5.15*
Rep	1	0.927	1.54
Lact x Gest	1	2.640	4.38*
Error	27	0.603	

In subsequent Appendix Tables, ** means significant at $P<0.01$ and * means significant at $P<0.05$.

Appendix Table 5. Analysis of Variance of Three Week Cumulative Weight Gain of Litters from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	42.85	-
Gest	1	10.34	-
Lact	1	209.82	4.34*
Rep	1	54.91	1.17
Lact x Gest	1	83.95	1.74
Error	27	47.08	

Appendix Table 6. Analysis of Variance of Nitrogen Intake (g) During Nitrogen Balance Trial From Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	1,677.47	8.27**
Gest	1	12.85	-
Lact	1	5,160.98	25.44**
Rep	1	40.28	-
Error	19	202.96	

Appendix Table 7. Analysis of Variance of Apparent Nitrogen Absorbed (g) During Nitrogen Balance Trial from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	1,846.87	7.75*
Gest	1	12.38	-
Lact	1	3,205.92	13.46**
Rep	1	65.85	-
Error	19	237.64	

Appendix Table 8. Analysis of Variance of Nitrogen Balance (g) During Nitrogen Balance Trial from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	254.50	1.45
Gest	1	15.20	-
Lact	1	2,654.32	15.30**
Rep	1	2,224.13	12.85**
Rep x Cycle	1	890.32	5.14*
Error	19	173.08	

Appendix Table 9. Analysis of Variance of Arginine in Sow Milk During Nitrogen Balance Trial from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	0.0132	6.6*
Gest	1	0.0167	8.79*
Lact	1	0.0001	-
Rep	1	0.0001	-
Gest x Lact	1	0.0080	4.00
Error	8	0.0019	-

Appendix Table 10. Analysis of Variance of Methionine in Sow Milk During Nitrogen Balance Trial from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	0.0086	5.30
Gest	1	0.0001	-
Lact	1	0.0009	-
Rep	1	0.0001	-
Gest x Lact	1	0.0174	10.67*
Error	8	0.0016	

Appendix Table 11. Analysis of Variance of Aspartic Acid in Sow Milk During Nitrogen Balance Trial During Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	0.0132	4.71
Gestation	1	0.0045	1.18
Lact	1	0.0045	1.18
Rep	1	0.0003	-
Gest x Lact	1	0.0189	6.75*
Error	8	0.0028	

Appendix Table 12. Analysis of Variance of Cystine in Sow Milk During Nitrogen Balance Trial from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	0.001	4.00
Gest	1	0.00006	2.40
Lact	1	0.0000	-
Rep	1	0.0000	-
Gest x Lact	1	0.0024	9.6*
Error	8	0.00025	

Appendix Table 13. Analysis of Variance of Proline in Sow Milk During Nitrogen Balance Trial from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	0.0268	3.22
Gest	1	0.0110	1.34
Lact	1	0.0102	1.24
Rep	1	0.0081	-
Gest x Lact	1	0.0593	7.23*
Error	8	0.0082	

Appendix Table 14. Analysis of Variance of Arginine (g/16 g Nitrogen) in Sow Milk During Nitrogen Balance Trial from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	14.22	8.01*
Gest	1	20.06	11.31**
Lact	1	0.04	-
Rep	1	0.06	-
Error	8	1.77	

Appendix Table 15. Analysis of Variance of Aspartic Acid (g/16 g Nitrogen) in Sow Milk During Nitrogen Balance Trial from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	2.90	3.70
Gest	1	3.26	4.23
Lact	1	3.65	4.73
Rep	1	2.10	2.72
Gest x Lact	1	4.90	6.36*
Error	8	0.77	

Appendix Table 16. Analysis of Variance of Cystine (g/16 g Nitrogen) in Sow Milk During Nitrogen Balance Trial from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	0.095	4.31
Gest	1	0.009	-
Lact	1	0.078	3.54
Rep	1	0.006	-
Gest x Lact	1	0.175	7.95*
Error	8	0.022	

Appendix Table 17. Analysis of Variance of Proline (g/16 g Nitrogen) in Sow Milk During Nitrogen Balance Trial from Three Reproductive Cycles - Experiment 1

Source of Variation	df	MS	F
Cycle	1	10.50	8.59*
Gest	1	2.88	2.35
Lact	1	6.91	5.65*
Rep	1	3.20	2.62
Gest x Lact	1	16.74	13.71**
Error	8	1.22	

Appendix Table 18. Analysis of Variance of Total Body Water (%) in Sows on Zero and 21st Days of Lactation and 14th Day Post Weaning - Experiment 1

Source of Variation	df	MS	F
Cycle	1	389.58	37.34**
Gest	1	1.11	-
Rep	1	1.56	-
Period	2	216.70	27.76**
Error	28	10.43	

Appendix Table 19. Analysis of Variance of Total Body Fat (%) in Sows on Zero and 21st Days of Lactation and 14th Day Post Weaning - Experiment 1

Source of Variation	df	MS	F
Cycle	1	758.88	37.94**
Gest	1	0.54	-
Lact	1	19.02	
Rep	1	1.32	-
Period	2	398.12	19.90**
Error	28	19.97	

Appendix Table 20. Analysis of Variance of Total Body Protein (%) in Sows on Zero and 21st Days of Lactation and 14th Day Post Weaning - Experiment 1

Source of Variation	df	MS	F
Cycle	1	25.17	24.90**
Gest	1	0.11	-
Lact	1	1.50	1.48
Rep	1	0.15	-
Period	2	22.60	22.37**
Error	28	1.01	

Appendix Table 21. Analysis of Variance of Total Body Mineral (%) in Sows on Zero and 21st Days of Lactation and 14th Day Post Weaning - Experiment 1

Source of Variation	df	MS	F
Cycle	1	1.07	26.75**
Gest	1	0.02	-
Lact	1	0.04	1.00
Rep	1	0.00	-
Period	1	0.89	22.25**
Error	28	0.04	

Appendix Table 22. Analysis of Variance of Sow Milk Yield (Kg/day) from 17th-20th Days of Lactation - Experiment 1

Source of Variation	df	MS	F
Cycle	1	31.78	19.03**
Gest	1	1.10	-
Lact	1	0.20	-
Rep	1	7.72	4.62*
Gest x Cycle	1	15.06	9.02**
Cycle x Rep	1	11.32	6.78*
Gest x Cycle x Rep	1	19.85	11.88**
Error	20	1.67	

Appendix Table 23. Analysis of Variance of Sow Milk Protein (%) on 21st Day of Lactation - Experiment 1

Source of Variation	df	MS	F
Cycle	1	1.05	5.27*
Gest	1	0.26	1.29
Lact	1	0.48	2.40
Rep	1	0.49	2.45
Cycle x Rep	1	1.38	6.90*
Cycle x Gest x Rep	1	1.46	7.30*
Gest x Lact x Rep	1	2.42	12.10**
Cycle x Gest x Lact x Rep	1	1.66	8.30**
Error	26	0.20	

Appendix Table 24. Outline of Experimental Design - Experiment 11

	First Cycle[1]		Second and Third Cycles	
Protein Level in a) Gestation (%)	Control (10.6)	Control + Lysine (10.9)	Control (10.6)	Control + Lysine (10.9)
b) Lactation (%)	Control (12.8)	Control + Lysine (12.8)	Control (12.8)	Control + Lysine (12.8)
No. of animals in Gestation	8	8	7	5
No. of animals in Lactation	5	5	6	6

[1] One cycle consists of a complete gestation-lactation period.

Note: Data from six sows from the first lactation were not included due to a scours outbreak. In addition, four sows were removed from the experiment after the first lactation due to reproductive failure.

Appendix Table 25. Amino Acid Composition (%) of Gestation and Lactation Rations - Experiment 11

Ration	Gestation		Lactation	
Protein (%)	Control (10.6)	Control ± Lysine (10.9)	Control (12.8)	Control ± Lysine (12.8)
Essential amino acids				
Arginine	0.43	0.40	0.54	0.62
Histidine	0.16	0.15	0.23	0.23
Isoleucine	0.26	0.27	0.37	0.36
Leucine	0.66	0.65	0.83	0.77
Lysine	0.29	0.47	0.61	0.72
Methionine	0.11	0.10	0.14	0.15
Phenylalanine	0.40	0.39	0.61	0.56
Threonine	0.27	0.26	0.39	0.37
Valine	0.40	0.38	0.54	0.52

- Continued -

Appendix Table 25. Amino Acid Composition (%) of Gestation and Lactation Rations - Experiment 11

Ration	Gestation		Lactation	
Protein (%)	Control (10.6)	Control ± Lysine (10.9)	Control (12.8)	Control ± Lysine (12.8)
Nonessential amino acids				
Alanine	0.46	0.44	0.56	0.53
Aspartic acid	0.53	0.53	0.81	0.76
Cystine	0.19	0.14	0.10	0.08
Glutamic acid	1.90	1.78	2.73	2.62
Glycine	0.36	0.35	0.45	0.42
Proline	0.87	0.71	1.13	1.34
Serine	0.36	0.36	0.49	0.57
Tyrosine	0.26	0.27	0.37	0.36

Appendix Table 26. Analysis of Variance - Experiment 11

Source of Variation	df
Cycle	1
Treatment	1
Cycle x Treatment	1
Error	24

Appendix Table 27. Analysis of Variance of Two Week Cumulative Weight Gain of Pigs from Two Reproductive Cycles - Experiment 11

Source of Variation	df	MS	F
Cycle	1	2.06	12.83**
Treatment	1	0.75	4.43*
Error	18	0.17	

Appendix Table 28. Analysis of Variance of Three Week Cumulative Weight Gain of Pigs from Two Reproductive Cycles - Experiment 11

Source of Variation	df	MS	F
Cycle	1	4.47	13.83**
Treatment	1	2.73	8.44**
Error	18	0.32	

Appendix Table 29. Analysis of Variance of Three Week Cumulative Weight Gain of Litters from Two Reproductive Cycles - Experiment 11

Source of Variation	df	MS	F
Cycle	1	786.90	20.65**
Treatment	1	169.41	4.45*
Error	18	38.07	

Appendix Table 30. Analysis of Variance of Number of Pigs Weaned at Three Weeks from Two Reproductive Cycles - Experiment 11

Source of Variation	df	MS	F
Cycle	1	32.30	15.17**
Treatment	1	2.91	1.40
Cycle x Treatment	1	12.82	6.02*
Error	18	2.13	

Appendix Table 31. Analysis of Variance of Feed Intake (Kg) During Nitrogen Balance Trial from Two Reproductive Cycles - Experiment 11

Source of Variation	df	MS	F
Cycle	1	11.160	11.80**
Treatment	1	0.105	-
Cycle x Treatment	1	0.002	-
Error	18	0.946	

Appendix Table 32. Analysis of Variance of Sow Milk Yield (Kg/day) from 17th-20th Days of Lactation - Experiment 11

Source of Variation	df	MS	F
Cycle	1	33.23	25.37**
Treatment	1	1.84	1.40
Error	18	1.31	

Appendix Table 33. Analysis of Variance of Isoleucine in Plasma (umoles/litre) of Sows During Gestation for Cycle 1 - Experiment 11

Source of Variation	df	MS	F
Treatment	1	2,824.6	15.66**
Time[1]	1	44.40	-
Error	16	180.36	

[1] Blood sampling time was 18 hours fasting and 3 hours post-prandial.

Appendix Table 34. Analysis of Variance of Leucine in Plasma (umoles/litre) of Sows During Gestation for Cycle 1 - Experiment 11

Source of Variation	df	MS	F
Treatment	1	3,299.11	4.67*
Time[1]	1	911.25	1.29
Error	16	705.18	

[1] See footnote 1, Appendix Table 33.

Appendix Table 35. Analysis of Variance of Lysine in Plasma (umoles/litre) of Sows During Gestation for Cycle 1 - Experiment 11

Source of Variation	df	MS	F
Treatment	1	17,222.45	6.36*
Time[1]	1	8,096.28	2.99
Error	16	2,704.64	

[1] See footnote 1, Appendix Table 33.

Appendix Table 36. Analysis of Variance of Phenylalanine in Plasma (umoles/litre) of Sows During Gestation for Cycle 1 - Experiment 11

Source of Variation	df	MS	F
Treatment	1	770.13	2.30
Time[1]	1	1,905.14	5.71*
Error	16	333.54	

[1]See footnote 1, Appendix Table 33.

Appendix Table 37. Analysis of Variance of Threonine in Plasma (umoles/litre) of Sows During Gestation for Cycle 1 - Experiment 11

Source of Variation	df	MS	F
Treatment	1	31,129.0	10.50**
Time[1]	1	19,480.3	6.57*
Error	16	2,964.3	

[1]See footnote 1, Appendix Table 33.

Appendix Table 38. Analysis of Variance of Glutamic Acid in Plasma (umoles/litre) of Sows During Gestation for Cycle 1 - Experiment 11

Source of Variation	df	MS	F
Treatment	1	27,367.24	5.60*
Time[1]	1	1,397.79	-
Error	16	4,883.33	

[1] See footnote 1, Appendix Table 33.

Appendix Table 39. Analysis of Variance of Proline in Plasma (umoles/litre) of Sows During Gestation for Cycle 1 - Experiment 11

Source of Variation	df	MS	F
Treatment	1	87,940.0	33.47**
Time[1]	1	11,283.0	4.02
Treatment x Time	1	17,675.8	6.73*
Error	16	2,627.0	

[1] See footnote 1, Appendix Table 33.

Appendix Table 40. Analysis of Variance of Proline in Plasma (umoles/litre) of Sows During Lactation for Cycle 1 - Experiment 11

Source of Variation	df	MS	F
Treatment	1	30,720.22	4.34
Time[1]	1	42,578.26	6.02*
Error	16	7,077.99	

[1]See footnote 1, Appendix Table 33.

Appendix Table 41. Analysis of Variance of Urea in Plasma (umoles/litre) of Sows During Gestation for Cycle 1 - Experiment 11

Source of Variation	df	MS	F
Treatment	1	1,799.78	5.97*
Time[1]	1	225.35	-
Error	16	299.83	-

[1]See footnote 1, Appendix Table 33.

Appendix Table 42. Analysis of Variance of Citrulline in Plasma (umoles/litre) of Sows During Gestation for Cycle 1 - Experiment 11

Source of Variation	df	MS	F
Treatment	1	7,698.1	14.49**
Time[1]	1	2,144.1	4.03
Error	16	531.3	

[1] See footnote 1, Appendix Table 33.

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