STUDIES OF BODY FLUIDS, NITROGEN BALANCE, SOME NUTRIENT DIGESTIBILITIES AND REPRODUCTIVE PERFORMANCE OF SOWS FED VARYING LEVELS OF PROTEIN

A Thesis

Presented to

The Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Brian Edward Milne

March 1965

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ABSTRACT

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Two trials were conducted during this investigation. In the first trial high, medium and low protein rations supplying 420, 240 and 170 g. of dietary protein per day respectively were fed to sows during gestation and prior to breeding. The second trial compared only the high and low protein rations with the low protein level diet being fed only for the last fifteen weeks of gestation. All animals received the high protein ration in lactation.

The ingredients of the low protein ration were corn, dehydrated alfalfa, and animal fat with a mineral-vitamin supplement. The other rations consisted of corn, dehydrated alfalfa and a mineral-vitamin supplement with the supplementary protein for the high protein ration provided by soybean meal and meat meal.

Due to fertility problems encountered in Trial I data from only a limited number of sows were obtained, this being especially applicable to the low protein ration. The problem was believed due to the use of animal tallow in

Trial I, so that lard was used as a source of animal fat in Trial II.

The lowering of the daily dietary protein levels to 240 and 170 g. of protein per day resulted in significantly lower weight gains in gestation for the low protein treatment animals in Trial I and while the medium protein animals gained less, the difference was not significant. Again in Trial II the animals on the low protein treatment gained less during the gestation period but the difference was not statistically significant.

No significant differences in apparent dry matter or crude protein digestibilities were noted in Trial I or Trial II.

Sows receiving the low protein ration during gestation retained significantly less protein in both Trial I and II but this was counteracted by lower nitrogen losses by these animals in lactation. In Trial II the composition of the products of gestation, namely fetuses, afterbirth and fetal fluids, was not affected by the different dietary regime received during the gestation period. The animals receiving the low level of protein actually stored more protein in the fetuses than the animals receiving the 420 g. level.

In Trial I and Trial II blood cell counts, haematocrit, haemoglobin and total serum protein levels were not

affected by the dietary regime, though all treatments showed a tendency towards "pseudo-anemia" in the latter stages of gestation. No significant changes in serum albumin or globulin levels as a percentage of total serum protein could be detected due to dietary protein level or stage of gestation.

The creatine, creatinine and total creatine-creatinine levels were studied in Trial II and the level of dietary protein during gestation had no significant effect upon these characteristics.

In Trial I all of the young of sows receiving the low protein ration were small and still born whereas no significant differences between numbers born, numbers stillborn or birth weights could be detected between the medium and high protein treatments in Trial I or the high and low protein treatments in Trial II. In Trial II the percentage of the live born young surviving to three weeks was considerably higher for the low protein treatment and this tended to counteract the higher numbers of stillbirths noted on this treatment. However, by the third week of lactation the young of the low protein treatment animals were significantly lighter in body weight than the young of the high protein treatment. In addition, overall litter weights were significantly lower for the low protein treatment animals, this being the result of a combination of the reduced numbers and lighter young at this stage.

In the lactation balance trials, the pigs of the low protein fed sows consumed almost the same quantity of milk as did the pigs suckling the sows fed high protein. However, since the protein content of the milk produced by the low protein fed sows was lower, protein intake by these pigs at one week was significantly decreased.

The feed consumption of the sows in Trial II during the lactation period was extremely poor. The low protein treatment animals ate more food in lactation and lost considerably less weight when compared with the high protein treatment group but differences were not significant.

The results of the study suggests that the feeding of 170 g. of protein per day during the last fifteen weeks of gestation of the sow does not result in significant effects upon reproductive performance, excepting that the protein content of the milk is decreased and three week litter weights may be lowered. In this study, intermittent scouring probably assisted the latter effect.

INTRODUCTION

In a pig enterprise, the efficiency of the reproductive cycle is of major importance, for unlike the dairy cow a sow's productive ability is dependent almost entirely upon her ability to rear young. The more pigs she produces that are viable to market weight the greater her value, as this spreads the sow's rearing and maintenance costs over a larger number of young.

It is generally well known that the nutritional status of the gilt and sow prior to breeding can affect the number of ova shed, a "flushing" effect being induced by increased feed allowances prior to mating. In addition diet in the gestation period can affect embryo survival, livability and post-natal growth. Failure of the latter two can be brought about by lowering or even complete lack of milk production following a period of poor nutrition in either gestation or lactation. Thus it can be seen that nutritional status in all three stages, pre-breeding, gestation and lactation can affect the efficiency of reproduction. For a comprehensive study all three stages must therefore be taken into account due to their interdependence upon one another.

To date National Research Council feed allowances for gestating gilts and sows have been based primarily upon information obtained in applied feeding trials and the esti-

mation of nutrient requirements has been made by extrapolating data obtained from growing animals. In other species, sheep and dairy cattle for instance, recommended feed allowances are increased towards the termination of gestation in accordance with the fact that the major developments of uterus and fetuses occur at this stage. A similar condition has been demonstrated in sows with some two-thirds of the products of gestation being laid down in the last one-third of pregnancy. However, in most North American feed recommendations no allowance is made for this, whereas most European countries increase feed levels by approximately one-third for the last month of gestation.

Many applied experiments varying the percentage of protein in a gestation ration have been reported with varying results. Only one recent report from North Carolina State, in which widely different levels of protein were fed, has been published to date. This showed that levels of 140 to 540 g. of protein fed per day had no significant effect upon young at birth and their post-natal growth.

After considering data on the protein contents of the products of gestation and the pattern of their accumulation it was decided to determine the effect three different levels of protein would have on reproductive performance in sows. As a standard the National Research Council recommended feed

level of 400 g. of protein per day was adopted, the other two levels being 60% and 42% of this. The protein content of the two latter rations was based upon theoretical estimates of earlier workers.

Most of the data presented concerns the National Research Council standard and the low level of protein, the study being more comprehensive than most attempted to date. Weight gain, feed consumption and litter data were criteria of interest. In addition, digestibility, nitrogen balance, creatinine and creatine excretion were determined and blood studies were conducted. The blood studies included cell counts, serum protein determinations and electrophoretic separation of serum proteins at various stages of the reproductive cycle. Also in the second of two trials conducted an attempt at assessing the total nitrogen content of the products of gestation was made by sacrificing the young at birth and collecting the fetal membranes and fluids.

LITERATURE REVIEW

Nutritional Factors Affecting Reproductive Performance

Excellent reviews of much of the data presented in the following pages have been presented by Duncan and Lodge (1960) and Lucas (1964).

"Sexual Maturity and Fertility"

The findings of Burger (1952) and Self *et al.* (1955) showed that while normally the gilt reaches sexual maturity between four and nine months of age, both over-feeding and under-feeding seem to delay the appearance of first oestrus.

Davidson (1930) discovered severe protein deficiency retarded sexual maturity to as late as eighteen months, whereas Fowler and Robertson (1954) observed protein quality could also affect a delay.

Nutritional effects on fertility were studied by Fishwick (1944) and (1945), who found a period of underfeeding early in life could cause infertility. King and Young (1957), found that sows on a low level of feed showed a higher incidence of infertility. In support of these conclusions Quaife (1952) observed that gilts and sows in improving condition conceived more readily and produced larger litters.

Hammond (1914) found that gilts often had fewer corpora lutea than sows; he also concluded that atrophy of fertilized ova early in pregnancy was not of great importance as more ova than the sow could support nutritionally were present at fertilization. However, Corner (1923) disagreed with Hammond (1914) concluding the atrophy to be due to defects of the germ cells themselves rather than lack of nutrients.

Protein levels did not appear to affect ovulation rate or litter size according to Davidson (1930) and Robertson et al. (1951b). A study by Casida (1956) compared gilts fed to appetite with gilts fed approximately 70% of this level prior to breeding and in early gestation. He noted that a higher percentage of ova were represented by embryos in the restricted animals while the full fed animals had more corpora lutea but a higher percentage showed signs of atrophy.

It would appear according to Self et al. (1955) that the greatest number of embryos at the 25th day of pregnancy are found in gilts full fed from puberty to mating with a restricted feeding thereafter. It may however, be possible to reduce the length of this full feeding period as Zimmerman et al. (1958), McGillivary et al. (1952) and Rigor et al. (1963) found that increased ovulation rates

occurred after raising feed intakes or supplementing rations with glucose or lard five to fourteen days prior to mating. This suggests that energy level is an important factor at this stage.

Fairbanks et al. (1945) and Gard et al. (1955) noted that the supplementation of a normal basal ration with 12% dehydrated alfalfa significantly reduced the number of still births and consequently increased litter numbers. Crystalline B vitamins significantly reduced the number of still births but were not as effective as dehydrated alfalfa. Other workers, namely Stothers (1957) and Palmer (1962), have noted the beneficial effects of feeding dehydrated alfalfa in the rations of breeding animals.

"Gestation"

Jesperson and Olsen (1939), Meyer (1940) and Olofsson (1950) concluded that there was a strong correlation between heavy birth weight and survival rate to ten weeks. Evidence concerning the effects of nutrition, especially protein levels upon birth weights, is very contradictory. Davidson (1930), Terill et al. (1953) and Clawson et al. (1963) all advocate that nutrition of the sow, as regards both protein levels, has little effect upon birth weight and litter size.

The Ontario Department of Agriculture (1947) found significant improvements in birth weights as protein levels

rose from 12% to 15% of the ration. Similar significant effects were observed by Tihonov (1957), and Stevenson and Ellis (1957). McKenzie (1928) and Davidson (1930) also state that the feeding regime in pregnancy can affect weight at birth and weaning, with protein deficient sows producing small stunted pigs.

In theory, providing the nutrient level of the mother is not too drastically curtailed, the conclusion of Davidson (1930), Terrill et al. (1953) and Clawson et al. (1963) would be expected. Crozier (1940) talks of a phenomenon he terms "Non-specific Invariance" which describes the partition of nutrients among the developing young in a litter. With each increment of one in a litter a constant fractional increase in material supplied to the young by the mother occurs, this material on the average being evenly partitioned among the young. However, prenatal mortalities could disturb this distribution causing variation in birth weights. The nutrients destined for the atrophying fetuses passing to normal fetuses where they are utilized, possibly causing increments in birth weights.

According to Hammond's theory on the utilization of nutrients in differential growth of tissues and organs, the most active or essential tissue in the body has a preferential claim on nutrients absorbed. Thus, in a full grown animal undergoing a period of inadequate nutrition, the uterus

would be high in the order of preference for nutrients. Only a small decrease in nutrients available for embryo growth would therefore be expected; since the fetuses consist of 85% to 90% water a negligible decrease in birth weight would be likely.

Energy

Overall Danish and Norwegian feed levels as recommended by Jespersen and Olsen (1939) and Valda et al. (1957) respectively are higher than National Research Council recommendations, though lower levels of feed are fed early in gestation and these are increased in the last three weeks of pregnancy.

Until recently, recommendations on feed levels for sows in Britain were empirical in that meal was fed according to condition. Six pounds of meal were fed in gestation with lactation allowances of two pounds for the sow and a pound of meal for each pig it was nursing. Lodge et al. (1961) found that these feed levels gave weight gains in gestation of 110-130 lb., weight losses in eight week lactations of 20-30 lb. and losses of 20-30 lb. in a one to two week post weaning period.

On studying these typical weight changes, Smith (1960) concluded that the building of body reserves during gestation and their dissipation in lactation and post weaning

is energetically inefficient. He thought a higher energetic efficiency would be obtained when sows were fed to gain weight in both gestation and lactation, this would mean a low feed intake in gestation and a high intake during lactation.

The data of some French workers was summarized by Salmon-Legagneur and Revat (1962), in which gains during pregnancy were termed pregnancy anabolism and they showed that this phenomenon occurred on a level of intake that would cover maintenance needs only in a non-pregnant animal. This would suggest that the composition of the weight gains in gestation must differ from that normally occurring or that the pregnant animal might be able to utilize feed more efficiently than a barren one. In another experiment gestation weight gains were limited to fifteen pounds in the last one-third of gestation and no significant effects on numbers or weights of young produced could be detected.

Other observations which these workers made were that high weight gains in pregnancy reduced appetite in lactation and were positively correlated with milk yield; and also efficiency of energy utilization with high feed levels in pregnancy and lactation was approximately four-fifths of that when low levels were fed in gestation followed by high levels in gestation.

Protein

Many workers, namely Evans (1929), Lenkeit and Gutte (1955a), Lenkeit et al. (1955b) report that during pregnancy an apparent storage of nitrogen occurs and this amounts to three or four times the nitrogen built into developing fetuses and related tissues, with the stored nitrogen being lost after parturition. It is of importance to know if these gains and losses in body weight and body nitrogen are of nutritional and therefore economic importance.

Duncan and Lodge (1958) recommend allowances of six to seven pounds per day of a meal containing 8% to 12% crude protein for a gestating animal. This provides a range of .48 to .84 lb. of crude protein per day. Experiments at the University of Leeds (Lucas (1964)) suggest if sows have grass pasture available, a daily allowance of five to seven pounds of meal consisting of ordinary cereals, minerals and vitamins is sufficient. The meal supplied 280 g. of protein per day but the grass could provide up to 100 g. of high quality protein per day. That is, 380 g. of protein per day could be obtained which is almost equivalent to the level recommended by the National Research Council (1959).

Boaz (1962) conducted an experiment in which the above meal was fed in concrete pens with no change in

numbers born or weight of progeny at birth and eight weeks. In comparison to sows receiving normal levels of dietary protein there was an increase in infertility after weaning. Livingstone (1962) carried out a histological examination of animals born to the above sows, finding muscle fibre diameter at birth was reduced but this effect was lost by the time the young reached 150 lb.

Recent data on the restricted feeding of sows are those of Clawson et al. (1963). They fed levels of three pounds and six pounds of meal throughout gestation, these levels providing 0.3 lb. to 1.2 lb. (136 to 544 g.) of crude protein daily. No effects on litter performance were observed. However, it should be noted that semi-purified diets were used, the protein source being soybean meal which has a considerably higher feeding value than cereal protein for pigs because of its amino acid balance.

Some workers have adopted a more intensive approach to the problem. Hennig (1959) determined the maintenance requirement of sows for nitrogen. After thirty-one balance trials with six sows, he found that the mean urinary excretion of endogenous nitrogen was 17.5 mg. per kilogram of body weight daily and the relationship between endogenous urinary N and live weight in kilograms could be expressed as:

Endogenous Urinary Nitrogen - $0.07619\ W^{0.7253}$.
(W = Weight of sow in kg.)
Endogenous fecal N was related to dry matter intake as well as body weight.

Endogenous Fecal Nitrogen - $0.1355\ W^{0.5952}$.
(W = Weight of sow in kg.)
From these findings Hennig estimated the minimum nitrogen requirement for maintenance of adult sows.

Maintenance Nitrogen - $0.1995\ W^{0.6654}$. g. N/day
(W = Weight of sow in kg.)
Excretion of endogenous N increased slightly in pregnancy averaging 0.36 g. N daily.

Smutts (1934) using data obtained by Brody on maintenance energy metabolism and using a ratio 12.5 mg. N/calorie of basal heat concluded that:
Protein requirement for maintenance/day - $0.88\ m^{0.734}$
(m = Weight of sow in kg.). Using these formulas and allowing for biological value and digestibility the maintenance requirement per day would be eighty-one and eighty-three grams of dietary crude protein for a 400 lb. sow.

Mitchell (1931) estimated the digestibility of crude protein to be 73% on a maize diet with a crude protein content

of 11%. The average daily nitrogen retention of five gilts receiving the above ration was 7.12 g. of nitrogen per day and storage did not increase over pregnancy despite increased demands for fetal growth. After allowances for digestibility and biological value and the use of a factor of 6.25 to convert grams of nitrogen to grams of protein, a retention of 7.12 g. of nitrogen per day was equivalent to 92 g. of dietary crude protein.

The protein content of the low protein ration in the experimental work of this thesis was therefore based upon a maintenance requirement of eighty-two grams of dietary protein per day plus a production requirement of ninety-two grams based on Mitchell's work giving a total requirement of 170 g. of dietary crude protein per day. This is approximately 42% of the level recommended by the National Research Council (1959).

Evans (1929) showed that three pregnant sows in nine balance periods of gestation retained 12.5 g. of nitrogen per day. Lenkeit et al. (1955b) found similar retentions to those reported by Evans.

Average retentions over the gestation period were approximately 1,450 g. of nitrogen or 9,063 g. of protein; this was equivalent to seventy-nine grams of protein per day. After allowances for digestibility (70%) and biological value (70%), an average intake of crude protein of 160 g. per day would be required to meet this. Using this as a production require-

ment and using the data presented by Hennig (1959) and Smutts (1934) to estimate maintenance requirement, a total requirement of 242 g. of dietary crude protein per day is indicated. This is 60% of the level recommended by the National Research Council (1959).

Tihonov (1957) fed a level of protein equivalent to that calculated above and found that by supplementing the ration, so that 300 g. of dietary protein per day were provided, resulted in 25% heavier birth and weaning weights.

It should be noted that the data of Mitchell (1931) are rather contradictory to those of Evans (1939) and Lenkeit et al. (1955b). The latter two workers used sows as experimental animals, while Mitchell (1931) used 250 lb. gilts and one would expect gilts of this weight to be growing, extra nitrogen being retained to meet this requirement, however, this was not the case. Mitchell's animals, which were growing and producing a litter, retained less nitrogen than animals which were only producing a litter and were apparently growing very little.

Both Mitchell (1931) and Moustgaard (1956) studied the composition of the products of gestation and their pattern of accumulation (see Fig. I P(16)). They concluded that only one-third of the nitrogen retained over gestation could be accounted for by the nitrogen present in fetuses, membranes, fluids and mammary tissues. Mitchell (1931) claimed the

excess retention went into the products of growth of the gilts, but Lenkeit et al. (1955b) noted that after parturition much of the excess protein was lost independently of milk production and even after termination of lactation excessive negative nitrogen balances were observed.

Moustgaard (1956) based his estimates of requirements on data related to the nitrogen contents of the products of gestation and the composition of the mammary glands at various stages of gestation. On this basis a drastic rise in requirement occurred after the seventy-fifth day of pregnancy (see Fig. II P(16)).

He estimated a mean daily requirement for sows to cover production would be 93.6 g. of dietary protein per day. This compares favourably to Mitchell's (1931) data where a production requirement of ninety-two g. of dietary protein per day was estimated.

Lactation

The nutrition of the litter in the suckling period is just as important as the prenatal stages. Salmon and Legagneur (1956) found a positive correlation between milk yield, the number of pigs at three weeks and weaning, but the number of pigs born did not determine milk yield. Fey (1958) suggested post farrowing weight gains appear to be more related to birth weight than milk yield, since smaller pigs suckled poorly and could not stimulate milk production.

FIGURE I

DEPOSITION OF PROTEIN IN THE UTERUS OF THE PREGNANT SOW

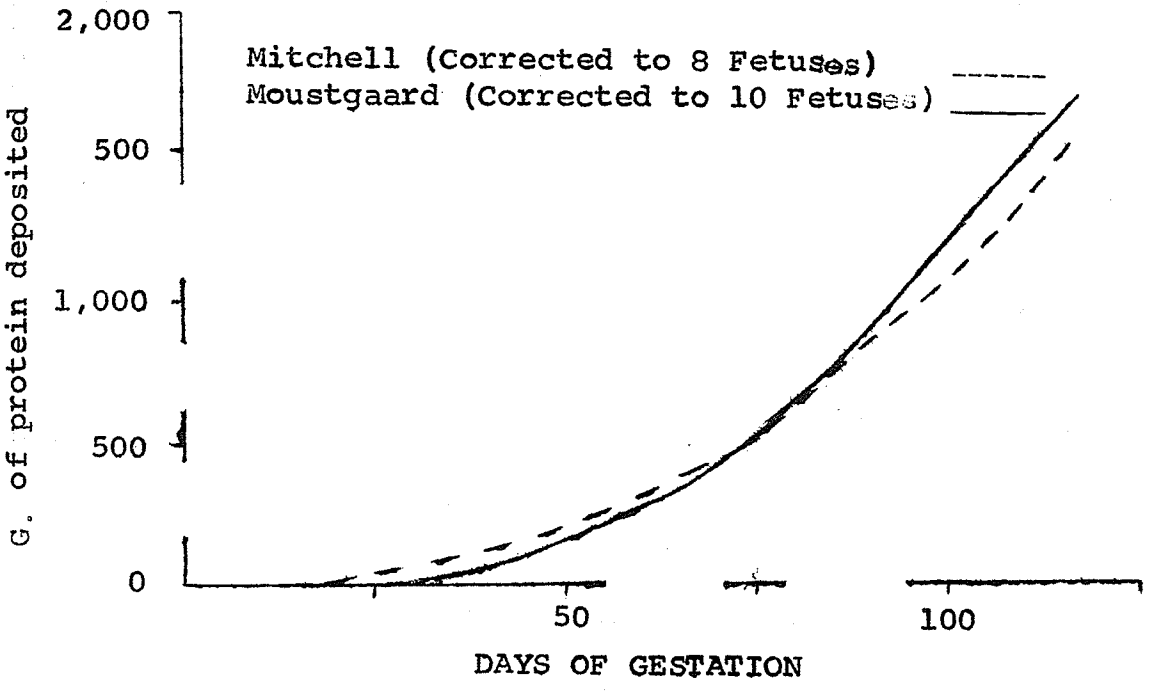
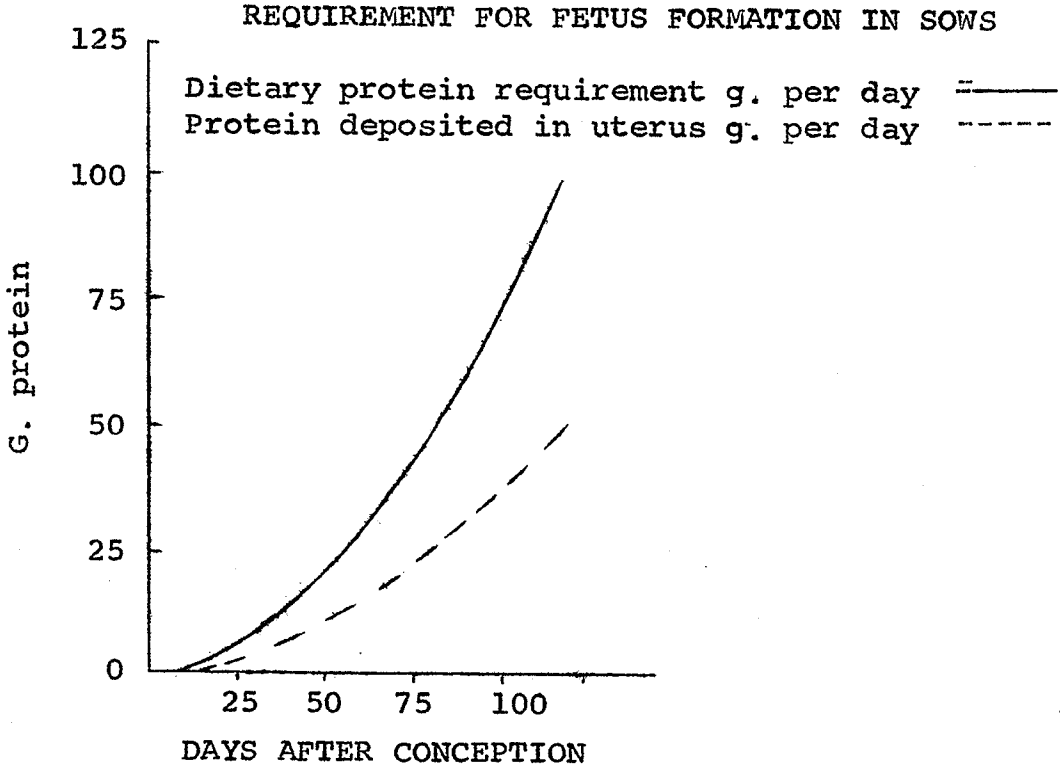


FIGURE II

PROTEIN RETENTION AND DIETARY CRUDE PROTEIN REQUIREMENT FOR FETUS FORMATION IN SOWS



Lenkeit and Gutte (1957) found the number of sucklings per day and the daily nutrient supply to the sow were important factors governing milk yield. Work et al. (1942), and Lodge (1959) confirmed that nutrition in lactation is the major factor controlling milk yield.

McKenzie (1926) studied the effects of pregnancy on growth, finding the condition of pregnancy did not affect growth in gilts and young sows, but lactation inhibited growth of gilts and sows even in well fed animals. The gilts and sows with larger litters lost more weight, gave more milk and reared heavier pigs.

There is some rather contradictory evidence regarding weight gains over the period of gestation. Wallace et al. (1934) and Zeller (1937) found that sows which gained most weight in gestation weaned larger litters and lost more weight in lactation. However, Vestal (1936) concluded that sows in a medium condition produced heavier and stronger pigs at birth and weaned more of them. Donald and Flemming (1938) could not confirm the findings of Zeller et al. (1937) and attempts to increase birth weights by liberal feeding of the sow resulted in failure.

Schafer and Granz (1955) and Lodge (1959) could find no correlation between loss of weight by the sow in lactation and litter size or weight at four weeks. Sows fed on a high plane in lactation lost less weight to weaning than sows on

a low plane. However, they lost more weight post weaning with the result that weights at re-breeding time were only slightly different.

Blood Studies

Due to interest in the possible effects low protein diets might have on the gestating sow, it was thought a comprehensive study should take into account effects on the hematopoietic system.

Miller et al. (1961) studied erythrocyte population, size and haemoglobin concentration from birth to maturity including the gestation period. Haemoglobin, haematocrit and red blood cell values were seen to fall towards late gestation but no change in mean corpuscular haemoglobin concentration occurred. According to Wintrobe (1956) this trend towards anemia is equivalent to that in humans termed physiological or pseudoanemia and is caused by hemodilution, i.e., a progressive increase in plasma volume during pregnancy. Friedell et al. (1951) and Miller et al. (1961) showed a relative increase of plasma or serum albumin-globulin ratio in sows and gilts during pregnancy which could be responsible for an increase in plasma volume similar to that observed by Wintrobe (1956).

Fraser (1938) and Miller et al. (1961) made the observation that reticulocyte numbers were very variable but

showed a slight tendency to increase at the stage of pseudo-anemia already mentioned.

Friedell et al. (1951) and Miller et al. (1961) published data on serum protein levels and composition in swine noting that total serum protein showed little change as gestation progressed but tended to fall slightly. Simultaneously, small increases in serum albumin levels occurred and corresponding decreases in the globulin fraction were observed.

Conversely, Smith et al. (1959)and Reboud et al. (1963) both working with humans observed a decrease in serum albumin simultaneously with an increase in a and b globulin fractions while globulin levels fell. Reboud et al. (1963) carried their study further noting a decrease in total serum protein levels, throughout gestation and immediately after delivery, followed by a rapid return to normal as lactation progressed. b globulins fell rapidly post partum but returned to normal within a week, while the fall in globulin levels throughout gestation was rectified shortly after parturition.

Digestibility and Balance Trials

Earlier workers Forbes (1915), Smuts (1935), Schneider (1932) and (1935) used chromium oxide and ferric oxide marker techniques in which ferric oxide was included in the feed at the commencement and termination of the trial for

one feeding, with chromium oxide being included in the interim period. All green coloured feces were collected with digestibilities being determined on chromium oxide marker and total collection basis.

Test periods ranged from three to seven days and levels of marker in the feed from 0.5% to 5%.

Schürch et al. (1952) compared chromium oxide indicator methods and marker to marker collection (i.e. total collection) finding no significant differences during a seven day collection period. Clawson et al. (1955) states that the indicator method of determining digestibility has an advantage on total collection methods providing suitable feces sampling methods can be developed and a minimum adjustment period of three days with chrominium oxide marker in the feed is adopted. Horvath (1958) reviewed other workers data and presented his own findings concluding that variations of 5% to 6% in chromic oxide and other nutrient concentrations occurred between morning and evening fecal samples, the variation probably being due to differential rates of passage of feed fractions through the intestine.

The above findings were utilized in designing our own digestibility and balance trial procedure. It should be noted that despite careful designing of balance trial methods Nehring (1957) after carrying out a seventy-five day study on growing pigs could only account for 77% to 87% of the

protein retained according to his balance studies when the animals were slaughtered.

Some explanation may be derived from the work of Consolazio *et al.* (1963) who found considerable losses of nitrogenous compounds could occur in human sweat. However, a pig does not possess sweat glands over its body surface but perhaps losses could occur in waste gases and saliva. In addition, scurf and waste hair could contribute to losses. Lenkeit *et al.* (1956) estimated that 4.32 g. of scurf and hair containing 51.2% protein is lost per day. This is equivalent to 2.2 g. of protein per day or 254 g. of protein over gestation.

Creatine and Creatinine

Lofgreen and Garret (1954), Miller and Blyth (1952) and Saffle *et al.* (1958) showed that the creatinine coefficient* in steers, humans, and hogs respectively is related to the amount of lean in the live animal.

Saffle *et al.* (1958) concluded that in 200 lb. barrows, blood serum creatinine, urinary creatinine and the creatinine coefficient were all positively correlated with measurements and analyses of carcass leaness. The "creatinine coefficient" is the more highly correlated item with r

*Creatinine coefficient = $\frac{\text{Milligrams of creatinine excreted daily}}{\text{Weight of animal in kilograms}}$

values ranging from 0.55 to 0.65. Negative correlations of creatinine coefficient to the fat contents of the animals ranged from r = -0.54 to -0.61. By extrapolating the data of Saffle *et al.* (1958) it was hoped that an indication of protein storage in gestation would be obtained.

EXPERIMENTAL

All animals used were sows bearing their second litter and were allotted to rations according to breeding and weight after weaning their first litter. All sows were crossbreds being 44% Landrace, 20% Wessex, 13% Welsh with small quantities of Minnesota No. 1, Berkshire, Tamworth and Yorkshire blood, excepting for a limited number of five Yorkshire sows. All sows were bred by Yorkshire boars.

Two trials were conducted. In the first, referred to as Trial I, two groups of animals were used. In group "a", ten sows were allotted to two rations, five to a high protein or standard ration and five to a medium protein ration. In group "b", sixteen sows were allotted to two groups, eight animals receiving the high protein ration and eight a low protein ration.

For the second trial, termed Trial II, another eighteen animals were bred and equal numbers were allotted to a high protein and a low protein ration.

In both trials sows were hand fed each morning and were kept in dirt lots for the major portion of breeding and gestation. As parturition approached animals were brought into the barn for farrowing.

In Trial I by the middle of December 1963, weather conditions were so severe that all of the sows were brought

into a heated barn and kept there until farrowing.

The ingredient composition of the high, medium and low protein rations are presented in Table I. Chemical and amino acid analyses were conducted using the Association of Agricultural Chemists (1960) methods and that of Moore et al. (1958) respectively. These data are presented in Tables II and III (Part a and b).

Dehydrated alfalfa was included in all rations at a 10% level, due to its reported beneficial effects on the reproductive performance of sows.

To avoid the complications involved with purified diets, corn and animal tallow in Trial I and corn and bakery lard in Trial II were used to reduce the level of protein fed and still maintain the same energy intake.

The reason for using bakery lard in Trial II was that some of the reproductive problems encountered in Trial I were thought to be due to complications arising from the use of a high percentage of animal tallow in the ration. By changing to a purer form of the animal fat and not placing the animals on this diet until one week after breeding it was hoped that the reproductive problems encountered in Trial I would be eliminated.

The rations were formulated so as to meet all National Research Council recommendations except level of protein.

TABLE I

INGREDIENT COMPOSITION OF RATIONS FED

Ingredient	High Protein	Medium Protein	Low Protein
Corn	78.0%	87.5%	62.5%
Soy-Bean Meal	7.5%	--	--
Meat Meal	2.5%	--	--
Dehydrated Alfalfa	10.0%	10.0%	10.0%
Animal Fat (Preservative Added)*	--	--	25.0%
Bone Meal	1.5%	2.0%	2.0%
Salt	0.5%	0.5%	0.5%
Vit. Premix/Ton			
Riboflavin	800 mg.	800 mg.	2,000 mg.
Pantothenic Acid	500 mg.	500 mg.	10,000 mg.
B_{12}	10 mg.	10 mg.	10 mg.

*In Trial I inedible tallow was used while in Trial II bakery lard was used.

TABLE II

CHEMICAL ANALYSIS OF RATIONS FED

	High Protein		Medium Protein	Low Protein	
	Trial I	Trial II	Trial I	Trial I	Trial II
Crude Protein %	14.59	14.15	11.60	8.82	7.96
Fat %	3.80	3.80	3.61	26.63	26.80
Crude Fibre %	4.70	4.70	4.46	3.87	3.84
Calcium %	0.64	0.64	0.56	0.63	0.63
Phosphorous %	0.50	0.50	0.45	0.42	0.42
T.D.N. (calculated)	75.60	75.60	74.50	107.20	107.20

TABLE III PART (A)

AMINO ACID COMPOSITION OF RATIONS FED. (PERCENTAGE OF RATION)

Trial I Ration	Glycine	Valine	Leucine	Iso-Leucine	Threonine	Tyrosine	Phenylalanine
High Protein	0.32	0.67	1.44	0.63	0.43	0.39	0.61
Medium Protein	0.29	0.46	1.20	0.41	0.33	0.36	0.31
Low Protein	0.26	0.50	1.20	0.47	0.26	0.29	0.36
Trial II							
High Protein	0.31	0.62	1.34	0.65	0.42	0.30	0.59
Low Protein	0.23	0.35	0.91	0.32	0.25	0.26	0.34
Estimated $\overline{X}$ Content of 12 Rations Recommended By U. S. Colleges						0.374*	

*Estimated from data presented by Cunha (1957).

TABLE III PART (B)

AMINO ACID COMPOSITION OF RATIONS FED. (PERCENTAGE OF RATION)

Trial I Ration	Histidine	Lysine	Arginine	Methionine	Cystine	Tryptophan
High Protein	0.32	0.48	0.64	0.24	0.11*	0.16*
Medium Protein	0.23	0.25	0.40	0.223	0.12*	0.10*
Low Protein	0.19	0.21	0.32	0.18	0.10*	0.09*
Trial II						
High Protein	0.34	0.45	0.65	0.26	0.11*	0.16*
Low Protein	0.18	0.20	0.30	0.17	0.09*	0.08*
Estimated $\bar{X}$ Content of 12 Rations Recommended By U. S. Colleges		0.78*	0.21*	0.29*	0.21*	0.19*

*Estimated from data presented by Cunha (1957).

Once weekly, all animals were weighed and their feed level adjusted so that the energy level recommended by the National Research Council for an animal of this weight was fed. After the first trial had been progressing for approximately two months, an upper limit to the quantity of feed an animal would receive was adopted because the animals were becoming excessively heavy and fat. The limitation came into force when the animal reached 450 lb., the limit being 6.5 lb. of feed per day for the high and medium protein rations and 4.6 lb. per day on the low protein diet. Water was available ad libitum in the dirt lots.

The rations were fed as a wet mash, excepting the low protein ration which was sufficiently moist in itself. A specific quantity of water was added to the meal, so that the meal content of any feed not eaten could be estimated fairly accurately.

As parturition approached, weights as close as possible to the commencement of farrowing and as close as possible to the cessation of farrowing were obtained. During lactation, a weight was obtained for the sow at least once weekly.

All young were weighed at birth, an injection of 2 cc of Pigdex complex was given intramuscularly at two to three days of age. Three week and weaning weights (i.e., six weeks) were obtained on both the young and sow, excepting

in Trial II when all data collection was terminated at the three week stage.

Digestibility and Nitrogen Balance Studies

In Trial I, digestibility and nitrogen balance studies were made on all animals at four stages of the experiment. The first prior to breeding gave an indication of the animals' nutritional status after weaning their first litters. Two more trials were carried out in the gestation period at approximately the forty day stage; the other at the ninety day stage, the fourth balance trial being conducted at the twenty-first day of lactation.

In Trial II digestibility nitrogen balance determinations were made prior to breeding and as frequently as time and facilities would permit in gestation. Two trials were conducted in lactation: the first on the sixth and seventh day, the second on the twentieth and twenty-first day of the lactation period.

After running several digestibility and nitrogen balance trials and referring to methods used by Forbes *et al.* (1915), Schneider *et al.* (1932) and Schneider *et al.* (1935) the procedure below was initially adopted as most suitable to our purpose for fecal collections.

To adjust the animals to the conditions, they were brought into the barn and placed in metabolism crates two

days prior to the beginning of the test period. During these two days a ferric oxide marker was placed in feed at a 1% level. On the morning of the third day in the crates a switch to feed containing 0.5% of chromium oxide was made and simultaneously catheters were inserted and urine collections commenced. The feed containing chromium oxide marker was fed for four days with a switch to meal containing ferric oxide being made on the fifth day.

All green feces which should be representative of the four days feed were collected and stored in the deep freeze. Collections were made as frequently as possible to prevent deterioration and possible loss of nitrogenous compounds into the air.

Once the final collection of feces had been made, all feces were thawed and homogenized with 10% hydrochloric acid. Two representative samples were taken for dry matter determinations, they were then ground and used for the determination of crude protein by macro-kjeldahl chromium oxide content by the method of Czarnocki et al. (1961) and crude fat determinations using ethyl ether as a solvent.

Urine was collected for four days with collections ceasing after the fifth feed. In Trial I collections were made in 10% hydrochloric acid, a layer of toluene being added to prevent contamination.

Trial II

The total fecal collection technique was abandoned as too time consuming and in place of this a chromium oxide marker was included in the animals feed at least three days prior to entry into the crates. The animals were then placed in the crates, catheters inserted and urine collected for a period of four days. All feces were collected daily while the animals were in the crates and at the end of the trial period the feces for each individual pig were homogenized in 10% hydrochloric acid and dried in an oven with the temperature not exceeding 90°F. When no change in weight occurred they were ground and analysed as described earlier.

A modification to the urine collection procedure was made to enable the determination of levels of creatine and creatinine excretion. No hydrochloric acid was added to the collection carboys and the urine was well mixed, measured in volume and an eighty milliliters sample taken every twenty-four hours, the daily samples were then placed in a refrigerator at a temperature below 4°C.

At the end of the four day trial period, the four samples for an individual sow were taken and a homogenate containing urine from all four samples was made up. The procedure used to ensure a representative homogenate entailed the summation of the daily volumes, with each daily volume

then calculated as a fraction of the total. This fraction was then used to determine the volume of the sample which was added to the final 100 ml. homogenate.

Total nitrogen was determined in duplicate by macro-kjeldahl. Creatine, creatinine determinations were made in duplicate in all samples using the technique as described by Richardson (1959).

The four day collections of urine in all balance trials were made by means of an inflatable Folley urethral catheter. This was an adaption of a method used in dairy cattle by Cunningham (1955).

It is important to note that the sow, contrary to many anatomy books, has a suburetheral diverticulum, which must be bypassed before complete insertion of the catheter may occur (Diagrams 1 and 2 P(136)).

It was found that if a piece of tygon tubing was attached to the catheter, the other end being suspended in a large carboy and a small weight attached to it, this allowed the sow sufficient movement in the crate without pulling the tube from the carboy. (Photo I and II).

With the weight and composition of the feed entering the animal known and the urinary and estimated fecal nitrogen and chromium oxide excretion measured, an estimation of the nitrogen retention was obtained; using both total collection and chromium oxide marker techniques in Trial I,

but only with a chromium oxide technique in Trial II.

The lactation balance trials were run as described by Duncan and Lodge (1959). The only alteration was that our sows were hand milked and were not milked dry, though a minimum sample of 10 ml. per milking teat was obtained.

Blood Studies

Blood samples were obtained every three weeks throughout Trial I using the method described by Carle and Dewhurst (1942). Five milliliters of blood were collected in a heparinized tube; a further eight to twelve milliliters were collected and allowed to coagulate for two to three hours. The sample was then centrifuged for twenty minutes at 1,500 R.P.M. and the serum was pipetted off and preserved in the deep freeze.

The heparinized blood was used for red and white cell counts; these counts were made using an electric gating mechanism as described by Grant et al. (1960) and Richar et al. (1959) respectively.

Duplicate haematocrit determinations were made using a heparinized capillary tube method. The cyanmet-hemoglobin standard method as recommended by the Department of National Health and Welfare (1961) was used in haemoglobin determinations.

The serum fraction was used in total serum protein

determinations by the micro-kjeldahl technique and electrophoretic patterns were obtained in duplicate on each sample, using the Sphinco Model R. paper electrophoresis system. The patterns obtained were assessed photometrically on a Spinco analytrol.

In Trial II the same determinations were made at less frequent intervals in gestation.

In Trial II it was decided to collect the products of gestation in their entirety and estimate the protein content of them.

Each sow was placed in a farrowing crate situated on a weigh scale. The crate was tilted at an angle so that all fluids would drain into plastic sheeting, from which it drained through muslin into a container. The crate and sheeting was washed down with dilute hydrochloric acid at termination of farrowing.

The fluids collected were homogenized, measured in volume and a sample taken for analysis by macro-kjeldahl. All solid materials such as afterbirth and membranes were collected, placed in the deep freeze and after freezing were cut into slices and put through a mincing machine. The minced material was then homogenized in a Hobart mixer with a sample taken for analysis.

To obtain an estimate of the composition of the young themselves, two litters in each group were sacrificed,

the piglets were killed at birth, weighed, placed in the deep freeze and then treated in a manner similar to the afterbirth and membranes.

Nitrogen determinations were done by macro-kjeldahl on freeze-dried samples of the above solids. Dry matter determinations were obtained in the freeze-dry process.

RESULTS AND DISCUSSION

Fertility

Out of forty-four animals originally bred only twenty-four reached the stage of parturition. In Trial Ia, only four out of ten animals produced litters, two were on the high protein treatment and two on the medium protein treatment. Of the three barren animals on the high protein treatment, one dislocated its spine. Post mortem examination showed a second to have cystic ovaries whereas the third had an apparently normal reproductive tract but continually returned to service. One of the animals receiving the medium protein treatment was apparently normal but continually returned to service while upon slaughter two others were found to have cystic ovaries.

In Trial Ib, only seven out of sixteen animals produced normal litters and all were receiving the high protein or standard ration. Upon slaughter the eighth animal on this treatment was found to have infantile reproductive organs. None of the eight animals on the low protein treatment produced normal litters. Although two sows reached the parturition stage, their young were small and still born. Of the six animals slaughtered three had cystic ovaries. The others were apparently normal as regards their reproductive tract but they continually returned to service. It would

appear that a ration effect on fertility had occurred but no explanation as to the origin of this effect can be offered. At first sight, the high percentage of stabilized tallow in the ration would appear to be the cause of the problem. But Zivkovic *et al.* (1963) fed high levels of tallow and observed no fertility effect. The extremely low conception rates encountered in Trial I a and b necessitated the second part of the experiment, namely Trial II.

Eighteen animals were originally allotted to treatments in Trial II, but data from only twelve are considered here. Of the nine animals allotted to the high protein treatment, eight conceived, but one animal died of infection and heat exhaustion in mid-gestation and a second animal farrowed nine weeks late. Data from both these animals were eliminated. The ninth animal allotted to this treatment was accidentally shipped following the pre-breeding balance trial.

Only six of the nine animals receiving the low protein ration conceived and of these one animal died of heat exhaustion just prior to farrowing. The young from this sow were well formed and above average weight for new born pigs. The gestation data of this animal were included in the following report and in the circumstances it was felt justified that the uterine contents could be included in data assessing the composition of the products of gestation for this group of animals. Of the three barren animals allotted to this

treatment, post mortem examination showed that one had cystic ovaries while the other two had apparently normal reproductive tracts but continually returned to service. The low conception rate for the low protein treatment animals was not due to a ration effect as all animals received the high protein ration pre-breeding.

The length of the gestation period was fairly consistent for both rations in Trial II, the high protein ration treatment had an average gestation period of 116.7 days whereas the low protein treatment animals exceeded this by 1.2 days, the gestation period being 117.9 days. No statistical differences were found in length of gestation between the two treatment groups. Before commencing the following report, it should be mentioned that due to the limited numbers of animals on the different treatments, especially in Trial I, and the very high variability encountered, statistically significant differences were obtained only in a limited number of instances.

Feed Consumption and Levels of Protein Fed Through Gestation

Feed and daily protein consumption data are presented in Table IV and Table V respectively.

At the commencement of the experiments, a slow increment in daily feed consumption was expected over the gestation period due to the sows expected increment in weight.

TABLE IV

FEED CONSUMPTION OF SOWS PREBREEDING AND IN GESTATION

(LB/DAY)

Trial I Treatment	No.of Sows Involved	Stage of Gestation					Entire Gestation
		Pre-Breeding	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	
High Protein a	2	6.50	6.73	6.15	6.40	6.60	6.47
High Protein b	7	5.70	6.08	6.66	6.53	6.12	6.34
High Protein a + b	9	5.83	6.28	6.54	6.50	6.22	6.37
Medium Protein (a)	2	6.50	5.00	6.76	6.44	6.74	6.29
Low Protein (b)	2	4.20	4.05	4.54	3.79	3.85	4.20
Trial II							
High Protein	6	6.10	6.29	6.04	5.93	6.45	6.23
Low Protein	6	6.01	5.26*	4.40	4.27	4.49	4.64

*6 lb.high protein ration for 1st week. 4.3 lb.of low protein ration for last 3 weeks. Overall $\bar{x}$ low protein ration only = 4.33 lb.

TABLE V

AVERAGE DAILY PROTEIN CONSUMPTION OF SOWS DURING GESTATION (G./DAY)

Trial I Treatment	No. of Sows Involved	Pre-Breeding	Stage of Gestation In Quarters 1st	2nd	3rd	4th	Entire Gestation
High Protein a	2	430	445	407	424	437	428
High Protein b	7	377	403	441	432	405	420
High Protein a + b	9	386	416	433	430	412	423
Medium Protein	2	350	269	356	347	355	331
Low Protein	2	168	162	182	152	154	168
Trial II							
High Protein	6	393	405	388	381	414	400
Low Protein	6	386	213*	159	154	162	172

*386 g. fed 1st week, 155 g. fed last 3 weeks of first quarter. For last 109 days $\bar{x}$ = 156.2 g. protein/day.

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However, it will be noted in Trial I a and b that this did not occur because the animals in Trial Ia were heavy at breeding and by the sixty-second day of gestation the animals were over-weight. These factors, combined with the effects of very hot weather resulted in a reluctance of the sows to eat their allotted daily feed. Subsequently a maximum feed level of 6.5 lb. per day was imposed on all sows exceeding 450 lb. in weight for animals receiving the high and medium protein ration and an upper limit of 4.6 lb. being applied to the low protein treatment animals. This limitation and lack of appetite in the latter stages of gestation resulted in lower feed consumption as gestation progressed in Trial Ia for animals receiving the standard protein ration. The medium protein ration animals in Trial Ia showed a slight increase in feed consumption over the last quarter of the gestation period, with the low consumption figure in the first quarter of gestation being explained by the fact that one sow was sick and ate very little feed in this period.

High and low protein ration animals in Trial Ib were all under the restricted feeding system mentioned from the commencement of gestation. Thus feed consumption levels rose to the end of the second quarter of gestation, then a combination of the upper limit to feed allowances at 450 lb. and lack of appetite in the latter stages of gestation resulted in a fall in average daily feed consumption in the

third and fourth quarters for both high and low protein treatment animals.

In Trial II the high protein treatment animals showed a lack of appetite in the second and third quarters of gestation, this phenomenon being most apparent on hot days. As a result, lower feed consumptions were observed in these quarters, with a slight rise occurring in the last quarter of gestation.

The low protein treatment animals in this trial received the high protein ration for the first week of gestation shown in Table IV. The average weight of feed received per day by these animals in the first week of gestation was 6.01 lb. and was equivalent to 386.4 g. of protein per day. For the last three weeks of this quarter an average of 4.33 lb. of feed, equivalent to 154.8 g. of protein per day was consumed. An average of 154.8 g. of protein per day was fed for the last 109 days of gestation. Due to the fairly constant composition of the rations fed, the average daily levels of protein received by the sows follow much the same pattern as the feed consumption figures.

The limitation on feed consumption imposed on the animals after they exceeded the 450 lb. weight limit resulted in energy restrictions during the latter part of gestation - some 4.6% and 15.4% below that recommended by the National Research Council for animals on the high and medium protein

rations respectively in Trial I. No feed limitations were necessary in the case of the low protein treatment, the animals never exceeding the 450 lb. weight limit. In Trial II the limitations during the latter part of gestation were 3.1% and 1.5% for high and low protein rations respectively. In Trial I these limitations came into effect on the sixty-second day of gestation for the high and medium protein rations and on the fifty-first and seventieth day of gestation for high and low protein treatments respectively in Trial II.

The above limitations are the percentage of extra energy which would have been fed to the animals if National Research Council recommendations had been followed. It should also be mentioned that had the feed limitations not been imposed, greater weight gains would presumably have occurred with consequent larger feed allowances. The percentage restrictions stated above are therefore only the apparent restrictions.

Weight Changes in Gestation and at Parturition

The average daily gains for the sows pre-breeding and at the four stages of gestation considered are presented in Table VI while Table VII presents data on the average weights and weight changes in gestation and at parturition.

In Trial I, with the exception of the low protein sows, there was no consistent pattern in the average daily weight gains, although contrary to feed consumption data, a tendency towards greater gains in the latter part of gestation occurred. Sows receiving the high protein ration gained more rapidly throughout gestation than animals on the other two treatments.

However, it will be noted that the animals on the medium protein ration lost weight during the first quarter of gestation. While this resulted in a significantly lower weight gain ($P < 0.05$) in comparison to the animals receiving the high protein ration, no explanation for this can be offered.

During the last half of gestation the animals on the low protein ration had a significantly lower weight gain than the animals receiving the high protein ration.

Table VII shows that animals receiving the medium and low protein ration treatments gained nineteen pounds and fifty-eight pounds less respectively than animals on the high

TABLE VI

AVERAGE DAILY GAIN OF SOWS PRIOR TO BREEDING AND IN GESTATION

(LB/DAY)

Trial I Treatment	No. of Sows Involved	Pre-Breeding	Stage of Gestation in Quarters				Entire Gestation
			1st	2nd	3rd	4th	
High Protein a	2	1.34	1.43	0.44	0.62	2.22	1.30
High Protein b	7	0.35	1.03	0.70	0.80	1.10	0.91
High Protein a + b	9	0.57	1.17	0.72	0.76	1.27	1.00
Medium Protein	2	1.03	-0.17	0.62	0.86	1.31	0.83
Low Protein	2	0	0.62	0.72	0.34	0.28	0.49
Trial II							
High Protein	6	-0.05	1.27	1.51	1.44	0.93	1.30
Low Protein	6	0.24	0.76	1.03	1.34	1.24	1.10

TABLE VII

AVERAGE WEIGHTS AND WEIGHT CHANGES IN GESTATION AND AT PARTURITION (LB.)

Trial I Treatment	No.of Detm.	Breeding Weight	Farrowing Weight	Weight Gained	Weight After Farrowing	Weight Lost Farrowing	Excess Weight Gained
High Protein a	2	492.5	642.0	148.5	584.0	58.0	90.5
High Protein b	7	390.0	495.0	105.0	458.8	36.2	68.8
High Protein a + b	9	412.5±68.8	527.4±80.3	114.9±29.0	483.4±35.3	44.0±18.3	70.9±15.41
Medium Protein	2	574.0± 8.5	650.0±25.4	76.0±29.0	599.0±26.5	51.0± 1.4	25.0± 9.10
Low Protein	2	361.5±15.2	418.5±45.2	57.0±27.6	400.5±29.2	18.0± 3.5	39.0± 8.16
Trial II							
High Protein	6	378.6±48.3	527.3±37.4	148.7±27.7	480.5±37.5	46.8±12.8	101.9± 6.41
Low Protein	6	382.6±46.7	509.5±43.5	125.9±52.3	468.1±48.3	41.4±10.9	84.5± 7.50

protein treatment. The latter was significantly lower ($P < 0.05$).

In Trial II no significant differences among treatment groups in weight gains in the various quarters of gestation were detected although the low protein animals gained twenty-two pounds less than animals receiving the standard ration.

Loss of weight at farrowing was another criterion of interest. In Trial I the only significant difference ($P < 0.01$) was shown by the animals on the low protein ration who lost an average of twenty-six pounds less than their counterparts on the high protein ration. The medium protein treatment animals had an average loss of weight of some seven pounds more than sows receiving the standard treatment.

Again in Trial II no significant differences could be detected, animals on the low protein ration losing an average of 41.3 lb. at parturition as compared to 46.8 lb. lost by the sows receiving the high protein ration.

DIGESTIBILITY DETERMINATIONS

In Trial I digestibility coefficients were determined using both total collection and an incorrect chromium oxide technique with the result that coefficients determined using the chromium oxide technique were consistently 4% to 6% lower than the total collection figures. An explanation of this is suggested by the work of Clawson (1955) who found that chromium oxide marker must be included in the feed for a minimum period of three days prior to fecal collection. The reason for this is that the chromium oxide concentration in the feces rises slowly over a period of three to four days reaching an equilibrium after this period.

Therefore, in Trial I feces were collected before this equilibrium point was reached with the result that the feces collected early in the balance trial had a lower chromium oxide content than those collected at the end, causing the fall in digestibilities noted. As a result of this, digestibilities in Trial I are reported using a total collection method and a chromium oxide technique in Trial II. It should be noted that more than one determination per sow per quarter of gestation are presented in the data from Trial II.

DRY MATTER DIGESTIBILITIES

The dry matter digestibilities in both trials and on all three rations were very consistent. The mean values for the various stages of the reproductive cycle and their standard errors are presented in Table VIII.

Overall mean digestibility coefficients in Trial I were 88.0, 90.0 and 89.0 for high, medium and low protein rations respectively. In Trial II the overall means were approximately five per cent to ten per cent lower, averages for gestation being 81.0 and 81.8 for high and low protein rations respectively.

At first sight it would appear that the digestibilities in Trial II were subject to the same error mentioned in Trial I. It is believed that this was not the case because the fall occurred only in dry matter and protein coefficients, the animal fat digestibilities remaining exactly the same as figures obtained in the total collection procedure. In Trial II, if the drop had been due to chromium oxide dilution, then it would have been observed in all three nutrient digestibilities as was the case in Trial I. Another reason for believing the fall to be real is that on collecting fecal samples on the eleventh and twelfth days after feeding chromium oxide marker, no further increments in fecal chromium oxide content could be detected and hence no increments in

TABLE VIII

$\bar{X}$ DRY MATTER DIGESTIBILITY DETERMINATIONS, PREBREEDING AND IN GESTATION

Trial I Treatment	Pre-Breeding[1]	Pre-Breeding[2]	Stage of Gestation in Quarters				Prebreeding and Gestation
			1st	2nd	3rd	4th	
High Protein a	85.0 (2)[3]	87.0 (4)		87.0 (2)		88.0 (2)	87.0 (6)
High Protein b	90.0 (8)			88.0 (7)		87.0 (7)	88.0 (22)
High Protein a+b	89.0±2.80[4] (10)			88.0±3.17 (9)		87.0±2.97 (9)	88.0±2.90 (28)
Medium Protein a	90.0±1.70 (2)	90.0±2.83 (4)		90.0±2.00 (2)		90.5±1.00 (2)	90.0±1.95 (6)
Low Protein b	90.5±3.35 (2)	89.5±3.25 (8)		88.0±2.10 (2)		85.5±1.90 (2)	88.6±3.15 (12)
Trial II							
High Protein	79.1±2.67 (6)	79.7±2.31 (9)	81.7±2.79 (9)	82.3±3.11 (11)	81.0±3.56 (11)	80.5±1.68 (12)	81.0±2.79 (49)
Low Protein	80.0±1.61 (6)	79.4±1.86 (9)	81.2±3.43 (9)	82.7±2.27 (8)	82.7±1.73 (9)	81.9±2.86 (15)	81.8±2.65 (47)

[1]Data from fertile animals only.
[2]Data from all animals bred.
[3]No. of determinations.
[4]Standard error.

dry matter or protein digestibilities were observed.

Other contributing factors to this fall in efficiency of food utilization from Trial I to Trial II could be the different group of sows used in Trial II and the new source of corn used in formulating the rations for this part of the experiment. The protein content of the new supply was 1.4% lower than the original. The lower protein content would suggest a lower digestibility if data of Schneider (1947) are considered.

When comparing the dry matter digestibility coefficients for the different rations in the two trials, no significant differences between rations or between pre-breeding and gestation values were detected.

CRUDE PROTEIN DIGESTIBILITIES

Digestibility coefficients obtained for crude protein were more variable than in the case of dry matter. The mean values and standard errors for crude protein digestibilities are presented in Table IX. It will be noted that, overall mean values in Trial I were 85.0, 84.0 and 80.0 for the high, medium and low protein rations respectively. As in the case of dry matter a marked fall occurred in Trial II, compared to Trial I with overall means being 77.0 for high protein and 76.0 for low protein rations. The cause of this fall in digestibilities can only be attributed to the

TABLE IX

$\bar{X}$ CRUDE PROTEIN DIGESTIBILITY DETERMINATIONS, PREBREEDING AND IN GESTATION

Trial I Treatment	Pre-Breeding[1]	Pre-Breeding[2]	Stage of Gestation in Quarters 1st	2nd	3rd	4th	Prebreeding and Gestation
High Protein a	85.0 (2)[3]	85.0 (4)		84.0 (2)		84.0 (2)	84.0 (6)
High Protein b	87.0 (8)			85.0 (7)		82.0 (7)	85.0 (22)
High Protein a+b	87.0±3.01[4] (10)			85.0±3.58 (9)		82.0±3.84 (9)	85.0±3.12 (28)
Medium Protein a	87.0±1.00 (2)	86.0±3.15 (4)		83.0±1.41 (2)		85.0±1.00 (2)	84.0±3.03 (6)
Low Protein b	79.2±4.07 (2)	80.0±2.93 (8)		81.0±1.41 (2)		75.0±2.24 (2)	80.0±4.23 (12)
Trial II							
High Protein	74.0±1.79 (6)	75.0±1.68 (9)	75.0±3.9 (9)	79.0±4.37 (11)	78.0±4.44 (11)	79.0±2.98 (13)	77.0±3.99 (50)
Low Protein	77.0±5.6 (6)	75.0±4.27 (9)	75.0±4.79 (9)	76.0±5.95 (8)	74.0±4.90 (9)	77.0±3.60 (15)	76.0±4.53 (47)

[1]Data from fertile animals only

[2]Data from all animals bred

[3]No. of determinations.

[4]Standard error.

factors already mentioned in the case of dry matter digestibilities.

In Trial I crude protein digestibilities were seen to fall slightly as gestation progressed but no statistically significant differences were detected.

In Trial II digestibility coefficients for the low protein ration tended to be slightly lower than the pre-breeding values for the high protein ration which these same animals received prior to breeding. On comparing the overall crude protein digestibilities of the high protein ration to that of the low protein ration, no significant differences were detected.

It should be noted that the above digestibilities are only apparent digestibility values, no allowances having been made for metabolic fecal nitrogen levels, which would have a greater effect on the low protein ration digestibility coefficients.

As metabolic fecal nitrogen was not determined in this experiment, only estimates of this factor may be proferred from the work of others. Variability of the values of metabolic fecal nitrogen as presented in the literature and summarized by Mitchell (1955) suggest that contributing factors other than variability of individuals must be present. Possible causes of this variability are body weight of the experimental animals, dietary crude fibre levels,

volume of feces, fecal dry matter content and intestinal motility as affected by the ration.

True crude protein digestibility values were determined using estimates of metabolic fecal nitrogen as determined by Mitchell (1955) and Hennig (1959). It was assumed that the sows had an average weight of 450 lb. and the corrected values for both trials are presented in Table X.

Mitchell (1955) combined the data of many workers with data from his own experiments and arrived at a mean value of 0.1 g. of metabolic fecal nitrogen per 100 g. of ingested food. Hennig (1959) directly determined the metabolic fecal nitrogen of six sows receiving protein free rations and arrived at an estimate approximately twice that of Mitchell's.

The true crude protein digestibilities as calculated using Mitchell's data to estimate metabolic fecal nitrogen proved more realistic overall than those based on metabolic fecal nitrogen levels as calculated using the formulas derived by Hennig (1959).

Firstly, it will be noted that the significantly higher apparent digestibility obtained for the high protein ration compared to the low protein ration was not real. The true digestibility values of the low protein ration was four to five per cent higher than the high protein ration. It

TABLE X

CORRECTED OR TRUE CRUDE PROTEIN DIGESTIBILITIES

Trial I Treatment	App. Digest.	True Dig. Mitchell Corr.	True Dig. Henning Corr.
High Protein a	84.0	88.4	94.0
High Protein b	85.0	89.3	95.0
High Protein a+b	85.0	89.4	95.0
Medium Protein	84.0	89.4	96.7
Low Protein	80.0	93.8	100+
Trial II			
High Protein	77.0	79.7	87.8
Low Protein	76.0	84.2	100+

might therefore, be suggested that the high fat level exerted a protein sparing effect.

Since Hennig's data were obtained using sows the resultant estimation of metabolic fecal nitrogen would seem most applicable to Trial I and II. It is possible that for the high protein ration Hennig's estimates of metabolic fecal nitrogen are reasonable, though possibly high due to the low fibre content of this ration, in comparison to Hennig's ration. However, Hennig's values must be high for the low protein ration and it can be assumed that the high levels of fat and smaller quantities of food fed would tend to reduce digestive secretions and sloughing and hence lower the metabolic fecal nitrogen.

CRUDE FAT DIGESTIBILITIES

The crude fat digestibilities on the high protein ration were very variable. This will be seen on examining the mean values and their standard errors presented in Table XI.

In Trial I overall mean digestibility coefficients for the high and medium protein rations were 66.8 and 68.4, the value for the high protein ration in Trial II being lower at 59.0.

Crude fat digestibilities for animals receiving a high percentage of animal fat in their diet were far less variable. The overall means for Trial I and Trial II were 88.9 and 89.6 respectively. No difference between pre-breeding and gestation values could be detected. It should be noted that percentage errors in determining fat levels for both feed and feces of animals receiving the high protein ration would be considerably higher than for the low protein treatment due to the small quantities present. This was probably a contributing factor to the high variance encountered in this determination.

Comparison of Digestibilities with Data of Other Workers

The digestibility values for dry matter, crude protein and ether extract presented above compare favourably

TABLE XI

$\bar{X}$ FAT DIGESTIBILITIES

Trial I Ration	Pre-Breeding[1]	Stage of Gestation in Quarters				Prebreeding and Gestation
		1st	2nd	3rd	4th	
High Protein	66.9± 9.20[3] (10)[2]		62.1±4.70 (9)		68.0± 6.35 (9)	66.8± 8.27 (28)
Medium Protein	66.9±19.82 (4)		72.5±4.74 (2)		67.1±12.92 (2)	68.4±16.92 (8)
Low Protein	89.3± 3.83 (8)		88.0±1.41 (2)		88.5± 1.00 (2)	88.9± 3.42 (12)
Trial II						
High Protein	59.2±12.24 (9)	62.8±9.95 (9)	55.4±7.87 (11)	56.9±16.51 (11)	61.2±12.64 (13)	59.0±13.41 (53)
Low Protein	57.9[4]± 8.97 (9)	87.9±5.46 (8)	91.4±3.16 (7)	87.7± 4.96 (10)	91.0± 4.11 (13)	89.6± 5.17 (38)

[1]Data from all animals bred.

[2]No. of determinations.

[3]Standard error.

[4]Animals receiving high protein ration at this stage.

to data presented by Schneider (1947) who obtained digestibility values of 80 to 90 for dry matter and 60 to 80 for crude protein when feeding corn rations to swine. Mitchell (1931) fed a ration similar to the medium protein ration in this experiment and obtained mean digestibilities of 82.8, 73.2 and 66.5 for dry matter, crude protein and ether extract respectively. These values compare very favourably with values in the second trial of this experiment.

Zivkovic et al. (1963) obtained digestibility coefficients of approximately 70, 75 and 90 for dry matter, crude protein and animal fat respectively and values of 62 to 75 for ether extract of rations containing no animal fat. These apparently low figures for dry matter digestibility can be explained on the basis that Zivkovic fed oats and barley as the major portion of his ration and this raised the fibre content four per cent to five per cent above the levels in the rations of the experiment reported here. Since fibre is relatively indigestible in the monogastric, lower dry matter digestibilities would be expected. Zivkovic's (1963) values for crude protein and ether extract digestibilities for rations containing animal fat or without animal fat compare very favourably with the values obtained in this experiment.

Protein Retentions in Pre-breeding and Gestation

Protein retained in grams per day varied considerably for sows on the same ration and at the same stage of gestation, this variability being more obvious in Trial I (Table XII) (Figure III).

Some of this variability may be attributed to three factors; firstly, the animals tended to go off feed after four to five days in the metabolism crate; secondly, a new urine collection technique was being developed and urinary bladder infections were encountered which led to excretion of foreign material in the urine. It is thought that these two problems only occurred in Trial I to any extent. Thus, other contributing factors must exist to explain the high variance in Trial II. The third factor stems from the work of Bressani and Braham (1964) who found that water intake could have a considerable effect on nitrogen balance of dogs. As water intake and urine excretion increased, nitrogen retention decreased, this being independent of the level of protein fed. Since the digestibility of dietary protein remained unchanged, the lower protein retentions resulted from increased urinary nitrogen.

To explain the variability in nitrogen balance results in this experiment one must assume that urine volume per period is related to water intake for the period. If this is the case, the considerable variation noticed in urine

TABLE XII

AVERAGE PROTEIN RETENTIONS (GRAMS/DAY) PREBREEDING AND AT DIFFERENT STAGES OF GESTATION

Trial I Treatment	Pre-Breeding[1]	Pre-Breeding[2]	Stage of Gestation in Quarters 1st	2nd	3rd	4th	Prebreeding and Gestation
High Protein a	174.0 (2)[3]			166.0 (2)		122.0 (2)	145.7 (2)
High Protein b	185.0 (8)			123.0 (7)		139.0 (7)	132.9 (7)
High Protein a+b	183.0±28.2[4] (10)			132.5± 20.6 (9)		136.3±14.3 (9)	134.4±45.4 (9)
Medium Protein a	136.0±26.5 (2)			99.0±102.1 (2)		65.0±22.6 (2)	82 ±98.2 (2)
Low Protein b	45.0±21.75 (8)			46.0± 72.1 (2)		34.0±41.7 (2)	40 ±16.2 (2)
Trial II							
High Protein	38.5±50.6 (6)	56.5±49.32 (9)	105.7±61.3 (9)	122.1± 46.3 (11)	114.3±20.3 (10)	153.5±24.0 (13)	123.9±24.0 (6)
Low Protein	82.2±41.5 (6)	76.0±37.65 (9)	12.2±61.8 (8)	32.2± 30.8 (7)	44.15±37.6 (8)	37.6±14.5 (14)	31.55±10.4 (6)

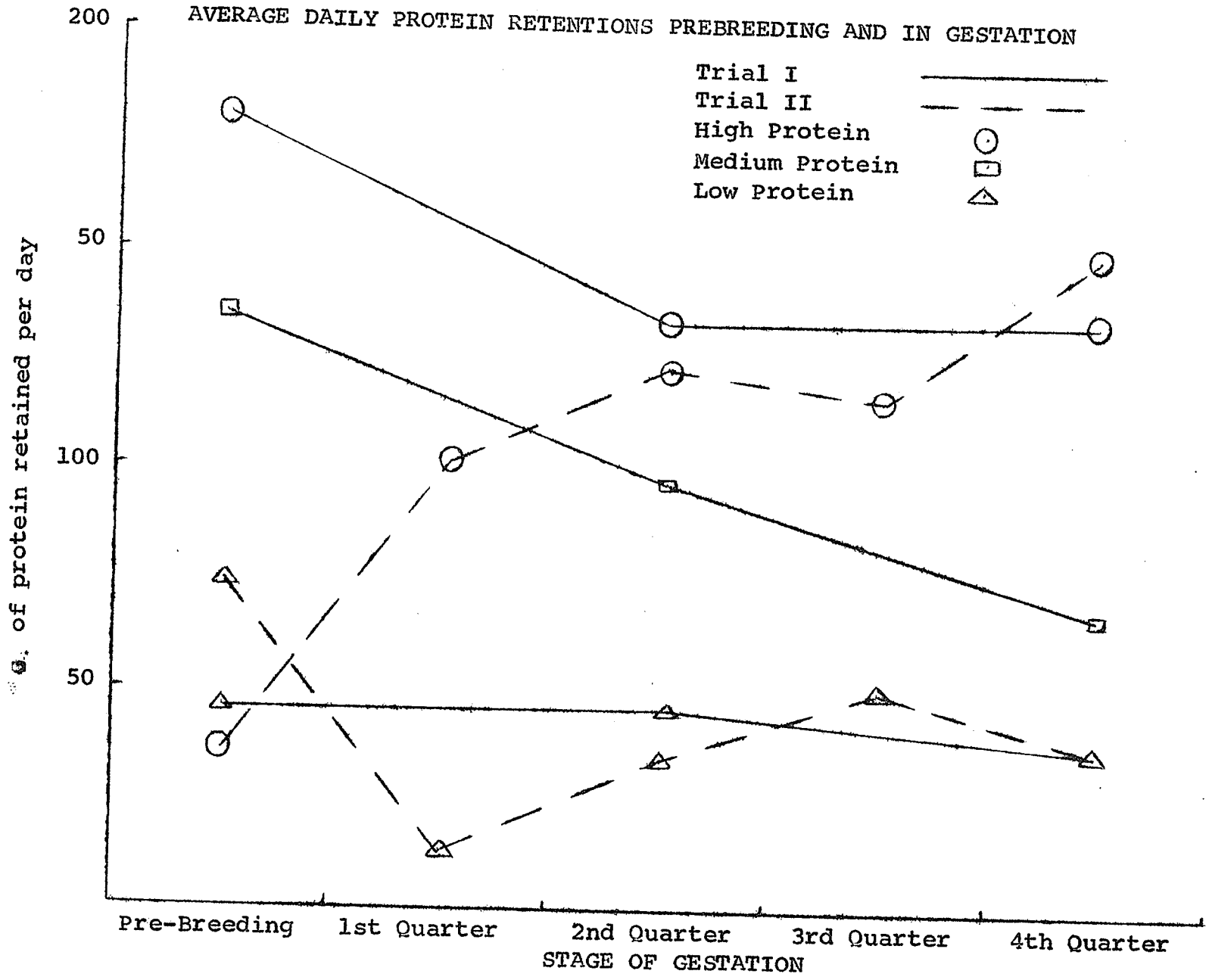
[1]Data from fertile animals only.

[2]Data from all animals bred.

[3]No. of determinations.

[4]Standard error.

FIGURE III


AVERAGE DAILY PROTEIN RETENTIONS PREBREEDING AND IN GESTATION
Trial I
Trial II
High Protein
Medium Protein
Low Protein
200
50
100
50
g. of protein retained per day
Pre-Breeding
1st Quarter
2nd Quarter
3rd Quarter
4th Quarter
STAGE OF GESTATION

volume from balance period to balance period could therefore be a contributing factor to the observed variation in nitrogen retentions.

It will be noted that in Trial I a slow fall in retentions occurred from pre-breeding to the fourth quarter of gestation; in contrast, retentions in Trial II rose sharply post breeding and then more slowly over the gestation period itself.

The fall in protein retention post breeding for animals receiving the high protein ration in Trial I was significant at the five per cent level only. Retentions of this group then leveled off at approximately 130 g. of protein per day and remained at this level till farrowing.

The two animals receiving the medium protein rations showed marked falls in retentions but significance was not achieved due to the small number of determinations and high standard deviations.

Pre-breeding retentions in Trial II were significantly lower ($P<0.05$) for animals which were to continue on the high protein ration. This was apparently due to two sows being in negative nitrogen balance during this period. This condition is not uncommon during the post-weaning period according to Lenkeit *et al.* (1956). Pre-breeding data were obtained on six other sows, which were allotted to rations but did not conceive. When these re-

tentions are added and the mean of nine sows per treatment is used there are no significant differences between pre-breeding retentions.

Immediately post breeding a significant rise ($P < 0.01$) in protein retentions occurred with animals on the high protein ration and this level of retention was maintained until the fourth quarter when a further significant rise ($P < 0.01$) occurred.

Animals receiving the low protein ration showed a marked fall in the first quarter of Trial II with some sows actually going into negative balance. This is explained by the animals being dropped suddenly from the high protein to the low protein ration one week post-breeding. It should be mentioned that in two balance trials following breeding, but prior to the animals being switched to the low protein ration, a mean retention of 134 g. of protein per day occurred. This was a level equivalent to that observed on the high protein ration just post-breeding. After this significant fall in retentions, ($P < 0.01$) a slow recovery occurred so that by the third quarter a significant rise ($P < 0.05$) had occurred and was maintained into the fourth quarter.

As regards differences in protein retentions between the low and high protein rations, animals receiving the low protein ration in Trial I retained significantly less

protein ($P < 0.01$) per day at all stages of gestation investigated. On comparing the retentions of animals receiving the medium protein ration with those receiving the high protein ration the fall in retentions was not so marked, a significantly lower retention ($P < 0.01$) occurring in the last quarter of gestation only.

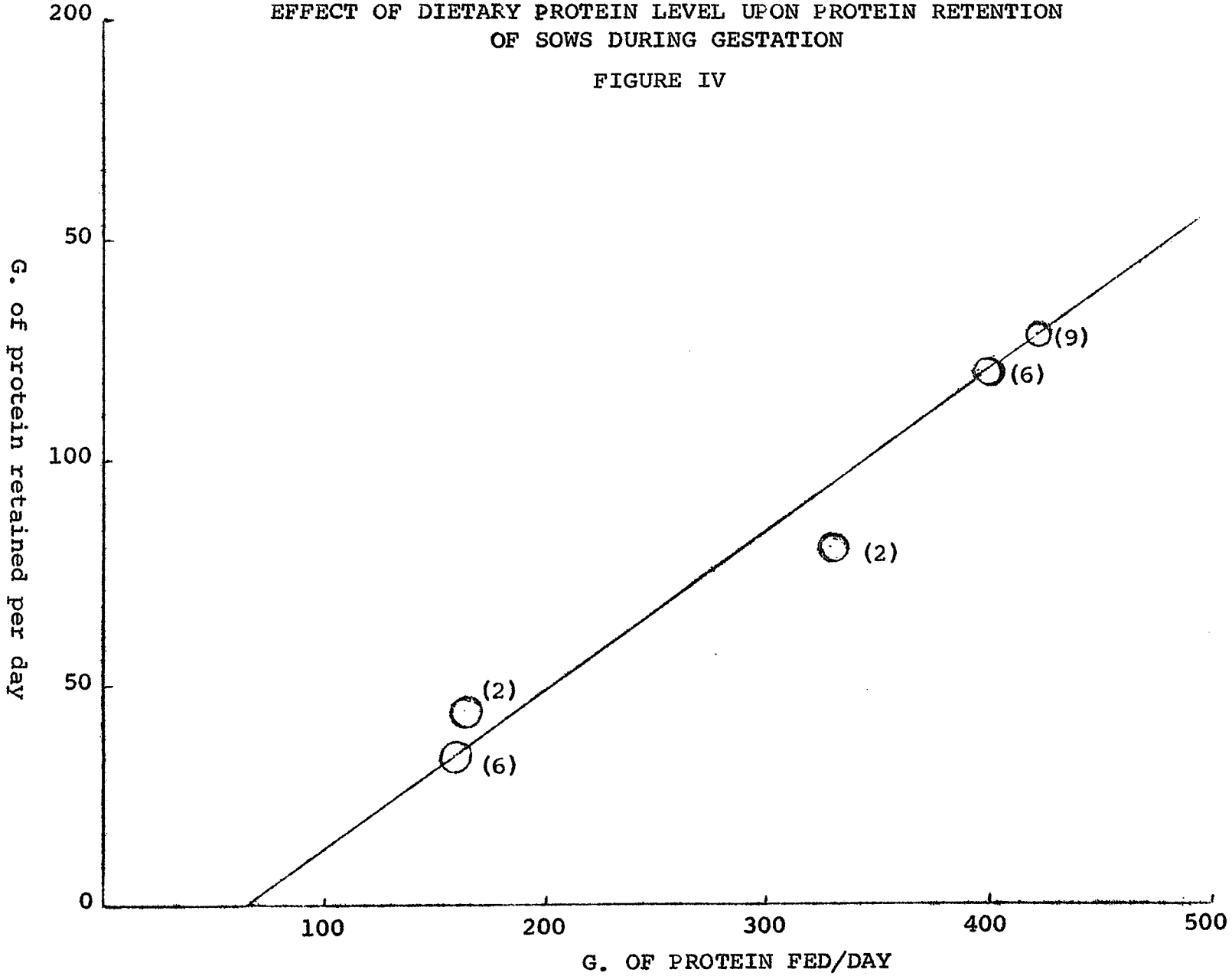
In Trial II all animals received the high protein ration prior to breeding but post-breeding half of the animals were switched to a low protein ration. Significantly lower retentions ($P < 0.01$) were observed at all stages of gestation for animals receiving this low protein ration in comparison with the animals continued on the high protein ration.

The overall retentions in gestation for the high protein treatment-animals in Trial I and II were higher than values presented by Mitchell (1931), Evans (1929) and Lenkeit *et al.* (1956) when they fed approximately 400 g. of protein or more per day to their animals.

Figure IV exemplifies the effect of dietary protein level upon protein retentions of sows during gestation from data obtained in Trial I and Trial II. Assuming that a straight line shows best the grams of protein retained per day at different levels of protein intake, it will be noted that zero retentions occurred at a protein intake of approximately 75 g. per day. The latter value is about

EFFECT OF DIETARY PROTEIN LEVEL UPON PROTEIN RETENTION OF SOWS DURING GESTATION

FIGURE IV



Numbers in parentheses are the numbers of determinations involved.

identical to the protein maintenance requirement established by Hennig (1959).

On considering the patterns of retention in Trial I, it is difficult to rationalize the data obtained, as it is atypical of other worker's observations and of what would be expected. That is, protein retentions were highest when bodily demands would theoretically be the lowest and were lowest when demands for protein to be used for development of uterus and litter are the highest.

Possible contributing factors to the above mentioned observations are firstly the animals were large and heavy in comparison to the average sow and presumably had body reserves in excess of normal animals. If this were the case, following early and rapid replenishment of lactation losses and initial storage, and following major modifications and laying down of tissue in the mammary glands, which occurs during the first third of gestation according to Folley (1956), the fetal requirements might have been small in comparison to the overall protein content of the animals.

Other factors are that very limited numbers were used on the medium and low protein treatments and higher feed consumption levels occurred at the commencement of gestation with the feed consumption of animals falling as gestation progressed.

It is important to note that despite the fact that

protein retentions do fall from pre-breeding to gestation at no point in gestation do daily retentions fall below the highest level of daily deposition in the uterus as estimated by Moustguard (1956). According to Moustguard's data, the highest daily deposition in the sow's uterus for an animal carrying ten fetuses is 50 g. of protein per day and this occurs close to parturition. Based on this, daily retentions of 100 g. of protein would easily cover any requirements for uterine deposition.

The pattern of retentions observed in Trial II for animals receiving the high protein treatment is more typical of what would be expected. The marked rise in retentions which occurred following breeding would have met the requirements of mammary tissue development and uterine modifications. The further rise in retentions in the latter stages of gestation occurred at a time when fetal and uterine demands were at a maximum.

The low protein treatment animals showed a marked fall in protein retentions when they were switched to the low protein ration one week post-breeding, a slow rise in retentions occurred to the third quarter with a slight decline occurring in the fourth quarter.

Mitchell (1931) found that no increments occurred in protein retention from pre-breeding to gestation, whereas both Evans (1929) and Lenkeit *et al.* (1956) observed that in-

crements in retention occurred immediately following conception. However, Evans (1929) could detect no further increments as gestation progressed, whereas Lenkeit et al. (1956) found further increments in protein retention in the latter stages of gestation. The pattern of retentions reported by Lenkeit et al. (1956) is typical of what one would expect, as was theorized by Moustguard (1956) and as was observed in Trial II of this experiment for animals receiving the high protein ration.

On comparing the data obtained in Trial I to that in Trial II markedly similar mean protein retentions occur. For the high protein ration a difference of ten grams of protein per day occurs with a difference of eight grams when comparing the low protein treatments.

Some estimate of the errors which have occurred in the balance trials conducted in these experiments is desirable. Therefore, in each treatment for both trials the average daily feed protein was reduced by the apparent digestibility coefficient to give an estimate of the protein absorbed into the body. Then, if the estimated loss of nitrogen in urine per day expressed as grams of protein and the estimated daily protein retentions are subtracted from this, a figure of zero should be noted. If the figure arrived at is considered to be the error and is expressed as a percentage of the protein originally fed to the animal,

the errors in Trial I are -14%, -10% and -14% for high, medium and low protein treatments respectively. A common error of 0.3% for both treatments occurred in Trial II. A contributing factor to the larger error in Trial I was the fact that animals tended to lose their appetite as the period in the metabolism crate lengthened.

Composition of Sacrificed Young, Fetal Membranes and Fetal Fluids

These data are presented in Table XIII. In both high and low protein treatments, two complete litters were sacrificed, also still born animals from all other litters were kept and treated as the sacrificed young. On completion of analysis, no statistically significant differences could be detected between the composition and contents of the sacrificed animals and the still born young. The data were therefore combined so that eighteen normal and four still born fetuses, a total of twenty-two animals were used in the high protein treatment data. Thirteen normal and ten still born fetuses, a total of twenty-three animals were used in the low protein treatment. It should be mentioned that one sow on the low protein treatment farrowed unexpectedly with the result that five dead young were found next morning. Whether these pigs were still born or were smothered in fetal membranes is unknown.

TABLE XIII

WEIGHT, % COMPOSITION, TOTAL DRY MATTER, AND TOTAL PROTEIN OF SACRIFICED YOUNG

Treatment	$\bar{X}$ Wt. of Pigs (g.)	$\bar{X}$ % Dry Matter	$\bar{X}$ Total Dry Matter (g.)/pig	$\bar{X}$ % Protein of Dry Matter	$\bar{X}$ Total Prot. (g.)/pig	Protein % of Original Wt.
Trial I						
High Protein	1387±272 (22)[1]	19.81±2.74	273.2±85.9	54.96±4.86	148.2±55.9	10.77±1.92
Low Protein	1379±295 (23)	20.18±2.89	298.4±76.3	55.74±2.25	159.2±19.7	11.22±2.00

$\bar{X}$ PROTEIN CONTENTS OF THE PRODUCTS OF GESTATION

Treatment	Protein Content Fluids and Membranes (g.)	Prot.Content of Pigs (g.)	Total Prot. Contents	Prot.Retnd. in Gest. Period	Prot. in Scurf (g.)	Extra Retention
Trial II						
High Protein	174±75 (6)	1257±256	1431±418	14,248±2760	254	12,563
Low Protein	213±29 (6)	1479±444	1692±445	3,628±1199	254	1,682

[1]No. of animals involved.

On comparing the two groups, a difference in average birth weight of only eight grams is noted. The low protein animals, though being slightly lighter, have a 0.37% higher dry matter content and a 0.78% higher protein content on a dry matter basis. As a result the total dry matter content of the low protein animals is some 15.2 g. greater than the high protein treatment while the total protein content follows a similar pattern being 11.0 g. per piglet greater on the low protein treatment.

When total protein content is expressed as a percentage of the original wet weight, the protein contents are almost identical with the high protein treatment fetuses containing .45% less than the low protein treatment fetuses.

Variability of these data were not great, but despite this no statistically significant differences could be detected between the composition and contents of the fetuses from the different treatments.

The weight and composition of the fetal fluids and membranes was extremely variable and although treatment differences were large, the differences were not statistically significant ($P>0.05$). It will be noticed from Table XIII that the total protein contents of membranes and fluids, fetuses and membranes, fluids and fetuses combined, are higher for the animals receiving the low protein treatment. Therefore, the low level of protein received in the gestation

ration did not apparently affect protein deposition in the uterus.

Total retentions during gestation are presented in Table XIV and here again similarities in values occur from Trial I to Trial II, the overall retentions for animals on the high protein ration were 15,410 g. and 14,260 g. of protein for Trial I and Trial II respectively. This compares to retentions of 4,600 g. and 3,680 g. of protein for the low protein treatment in Trial I and Trial II respectively.

Thus, the overall retention in gestation for animals on the low protein ration was approximately one quarter that retained by animals receiving the high protein ration. After deducting the values of protein lost at parturition in membranes, fluids, young and allowing for losses in scurf and hair as estimated by Lenkeit et al. (1956), an extra protein retention still occurred on both treatments. These data are presented in Table XIII.

This protein is presumably utilized in development of mammary tissue and extra weight gains in gestation over and above the weight losses incurred at farrowing. These extra weight gains range from 40 to 100 lb. and increase with the gestation ration protein content.

If these extra protein gains are of a similar composition to that of the original animal, that is, ten

per cent protein, (Morrison (1957), then they account for some 4 - 5,000 g. of the excess protein retained in gestation by the high protein animals and 3,400 g. for the low protein treatment. For animals receiving the high protein ration a storage effect must therefore occur or false retentions are being detected as was noted by Nehring (1956).

Errors of this magnitude seem unlikely in this experiment, because errors in urine collection and analyses would be very small due to the mechanism of collection and processing. Also losses of nitrogen from feces during the processing and drying as suggested by Manoukas et al. (1964) were considered and in six balance trials analyses were conducted on both wet and dried samples. No significant differences in total nitrogen content of the feces could be detected between the two procedures, suggesting that losses, if any, were insignificant.

A further factor to be considered is that for nine infertile animals, five on the high protein treatment and four on the low protein treatment, on which a series of balance trials were run, the protein retentions six weeks post breeding showed an average of +3 g. of protein per day with a standard error of 12.5 g. Increments in weight of the animals were negligible, suggesting that once deficiencies due to lactation had been replenished further retentions did not occur. This would help repudiate

the claim that undetected errors in the balance trials were not occurring.

Efficiency of Protein Utilization

In Trial I and II as the level of protein consumed or as a percentage of the ration falls, the efficiency of utilization falls, this is seen in Table XIV, where efficiency of utilization is defined as:

$$\text{Efficiency of Utilization} = \frac{\text{protein retained (g./day) in gestation}}{\text{g. of protein fed per day in gestation}}$$

In addition to the above ratio, the ratio of protein retained to protein apparently absorbed and the ratio of protein retained to the true protein absorbed were considered. The latter involved estimating metabolic fecal nitrogen levels and the estimates made by Mitchell (1955) were used in all these calculations. The data are presented in Table XIV. A further estimate of efficiency of protein utilization involved the comparison of retained protein with absorbed protein for productive purposes. The latter value was obtained by subtracting metabolic fecal and endogenous urinary nitrogen from the absorbed nitrogen.

Percentage utilizations of protein for the medium and low protein rations are approximately the same being 24.8% and 23.8% respectively in Trial I and 19.9% for the low protein treatment in Trial II.

In Trial I and II efficiency of utilization of the high protein ration was 32% and 31% respectively, a rise of seven to ten per cent. A possible reason for this may have been the soybean and meat meal protein sources in the ration.

It will be noted that when either the grams of protein apparently retained or grams of protein truly absorbed are used in the denominator for calculating efficiency of protein utilization, little change occurs in the difference between the high and low protein treatments. However, when the daily protein absorbed for productive purposes is used in the denominator, in Trial I the efficiency of protein utilization is higher for the low protein ration and in Trial II the low protein animals have a value close to that of the high protein treatment.

Based on these results the balance of amino acids would appear to be adequate suggesting that retentions on the low protein diet occur despite lower levels of amino acids available for absorption and building into body tissues.

On estimating the efficiency of protein utilization for the rations of Evans (1929) and Lenkeit *et al.* (1956) (note Table XIV) values of approximately 15% and 17% respectively were obtained. These low values might be explained by the fact that the protein levels of 500 and 525 g. per day fed by these two workers were in excess of the

TABLE XIV

PROTEIN RETENTIONS AND EFFICIENCY OF PROTEIN UTILIZATION IN GESTATION

Treatment	G. Prot. Fed/Day	$\bar{X}$ Rtn. /Day	Total Retnd.	% Protein in Ration	% Protein Fed Utilized*	Est.g.Prot. Retnd./g.Prot. App.Retnd. %	Est.g.Prot. Retnd./g.Prot. Truly Absorb.	Est.g.Prot. Retnd./Prot. Absorb. for Prod.purposes
Mitchell	392	44.5	5117	11.0	17.8			
Evans	523	78.2	8994	17.0	14.9			
Lenkeit	506	85.4	9831	17.0	16.9			
Trial I								
High Protein	418	134.0	15410	14.0	32.0	37.3	35.6	42.5
Medium Protein	331	82.0	9430	11.0	24.8	29.4	27.7	35.2
Low Protein	168	40.0	4600	8.0	23.8	29.8	25.6	44.9
Trial II								
High Protein	400	124.0	14260	14.0	31.0	40.2	38.8	47.1
Low Protein	161	32.0	3680	7.5	19.9	26.8	24.4	43.2

*G. protein retained/g. protein fed.

quantities the animals could handle so that deamination and excretion of excess amino acids occurred.

Mitchell (1931) fed daily approximately 400 g. of protein of apparently low biological value. The low efficiency of utilization which resulted was probably due to an excess of non-essential amino acids. The latter would then be deaminated and lost to the body resulting in lower efficiency of utilization as defined here.

Urinary Nitrogen Excretion and Urine Volume

Daily urinary nitrogen excretion and urine volume were very variable, as would be expected, it being the complement of the nitrogen and protein retentions. These data are presented in Tables XV and XVI, and graphically shown in Figures V and VI.

Despite considerable changes in urinary nitrogen excretion no significant differences could be detected in urine levels at different stages of gestation on the same treatments in Trial I. However, significantly lower urinary nitrogen levels occurred for animals receiving the low protein ration ($P < 0.05$) when compared to the high protein treatment.

In Trial II no significant differences in daily urinary nitrogen levels at different stages of gestation could be detected on the high protein ration but on the low

protein treatment significant falls in daily urinary nitrogen levels occurred from pre-breeding to the first quarter ($P < 0.05$) and from pre-breeding to the second quarter ($P < 0.01$), this was presumably due to the lower protein levels which were fed at this stage.

Again urinary nitrogen excretion was significantly lower at the one per cent level for animals on the low protein ration for the second, third and fourth quarters of gestation in comparison to the sows on the high protein ration.

On comparing levels of urinary nitrogen excreted to urine volume per day the animals receiving the high and medium protein rations showed a distinctly similar pattern at most stages of gestation, that is the higher the daily nitrogen excretion, the higher the daily urine volume. However, despite very large mean differences in daily urine volume for animals on different treatments, the variation was so high that no statistical differences could be detected.

Also the higher the daily urinary nitrogen the greater the level of nitrogen per 100 ml. of urine, so that on the high protein ration from .54 to .67 g. of nitrogen per 100 ml. of urine were excreted while the equivalent figures for the low protein ration treatment were .27 to .46 g. of nitrogen per 100 ml.

As water ingestation levels apparently affect

nitrogen balance in animals (Bressani and Braham (1964)) some control of the quantities of ingested water during a nitrogen balance trial might be desirable, to reduce the variability of nitrogen retention data. The inconvenience of such variability has already been well demonstrated in this experiment. It should be noted however, that the validity of any data collected under controlled water ingestion conditions may well be questionable. For example, if experimental animals undergo conditions of restricted water consumption during a balance period, the nitrogen flushing effect noted by Bressani and Braham (1964) would not occur. On returning these animals to normal water consumption levels, lower nitrogen retentions would occur due to the flushing effect of the increased water intake. However, it is suggested that for nitrogen balance experiments some control or record of ingested water should be made to reduce variability of results and enhance their interpretation, especially where treatment differences are likely to be small.

TABLE XV

$\bar{X}$ URINARY NITROGEN EXCRETIONS (GRAMS N/DAY x 6.25)

Trial I Ration	Pre-Breeding	Stage of Gestation in Quarters 1st	2nd	3rd	4th	Gestation Only
High Protein	99.6± 44.1[2] (10)[1]		126.5± 48.7 (9)		140.3±50.9 (9)	133.0±39.8 (9)
Medium Protein	86.0±116.6 (2)		220.0±113.1 (2)		104.5± 3.6 (2)	162.0±56.2 (2)
Low Protein	53.1± 18.5 (8)		56.5± 30.1 (2)		85.0± 7.1 (2)	70.5±22.1 (2)
Trial II						
High Protein	214.0± 78.6 (6)	198.0±60.1 (9)	192.3± 60.1 (11)	212.9±21.9 (11)	176.3±45.8 (13)	194.8±35.3 (6)
Low Protein	198.0± 42.0 (6)	107.8±16.4 (7)	84.7± 23.1 (8)	89.8±24.9 (10)	93.9± 4.9 (14)	94.0±16.5 (6)

[1]No. of determinations.

[2]Standard errors.

TABLE XVI

URINARY VOLUME (ML. PER DAY)

Trial I Ration	Pre-Breeding	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
High Protein	5619±1904[2] (9)[1]		5227±2160 (9)		4984±1463 (9)
Medium Protein	6579±5804 (2)		6678±5170 (2)		6045±1967 (2)
Low Protein	3840±1670 (2)		4255±1851 (2)		3458± 179 (2)
Trial II					
High Protein	5106±1774 (6)	5760±1824 (9)	4839±1328 (11)	5695±1006 (12)	4348±2200 (14)
Low Protein	5334± 892 (6)	5098±1510 (9)	5046±1530 (8)	3827±1446 (9)	3260±1241 (13)

[1]No. of determinations.

[2]Standard errors.

FIGURE V

AVERAGE DAILY URINARY NITROGEN EXCRETION PREBREEDING AND IN GESTATION

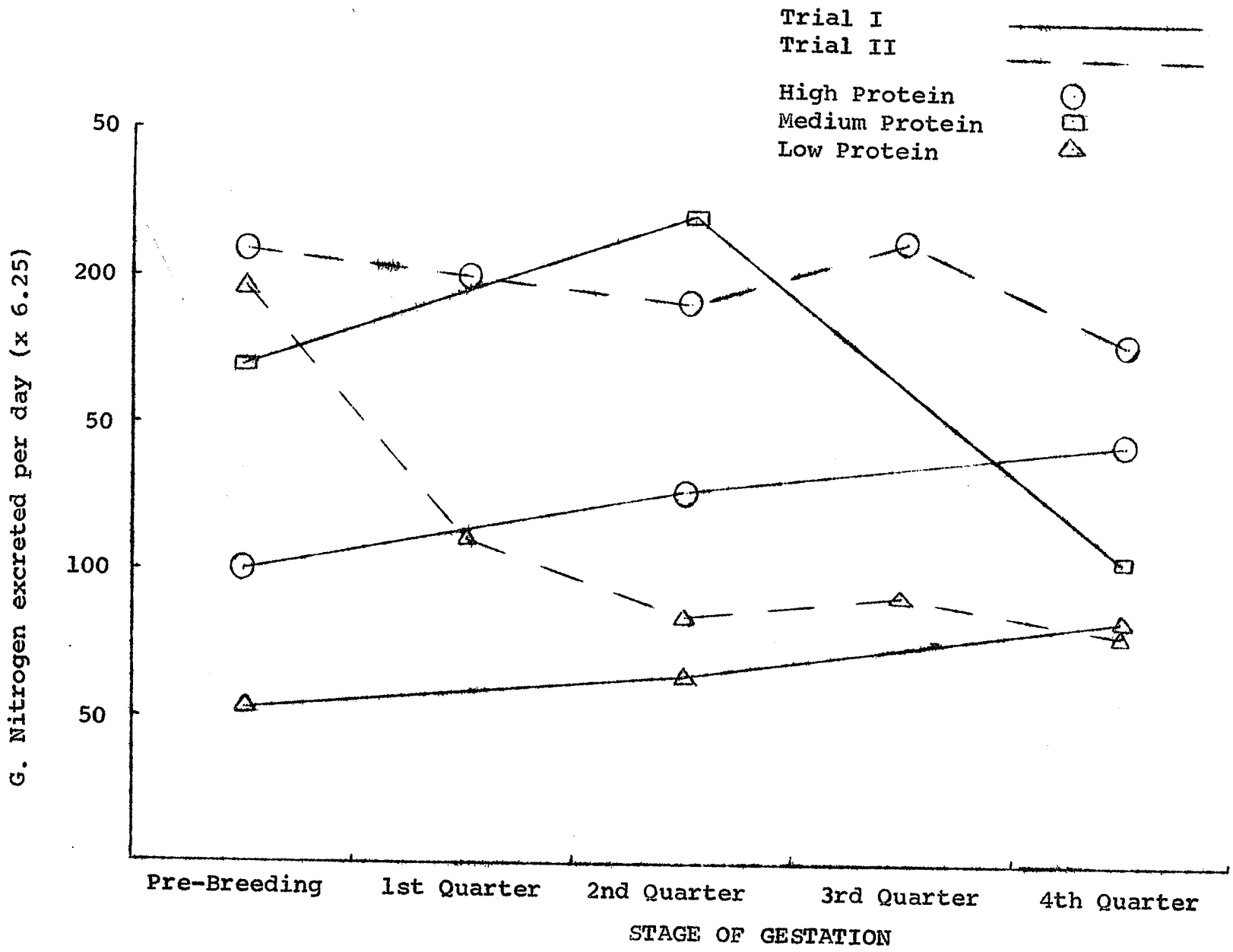
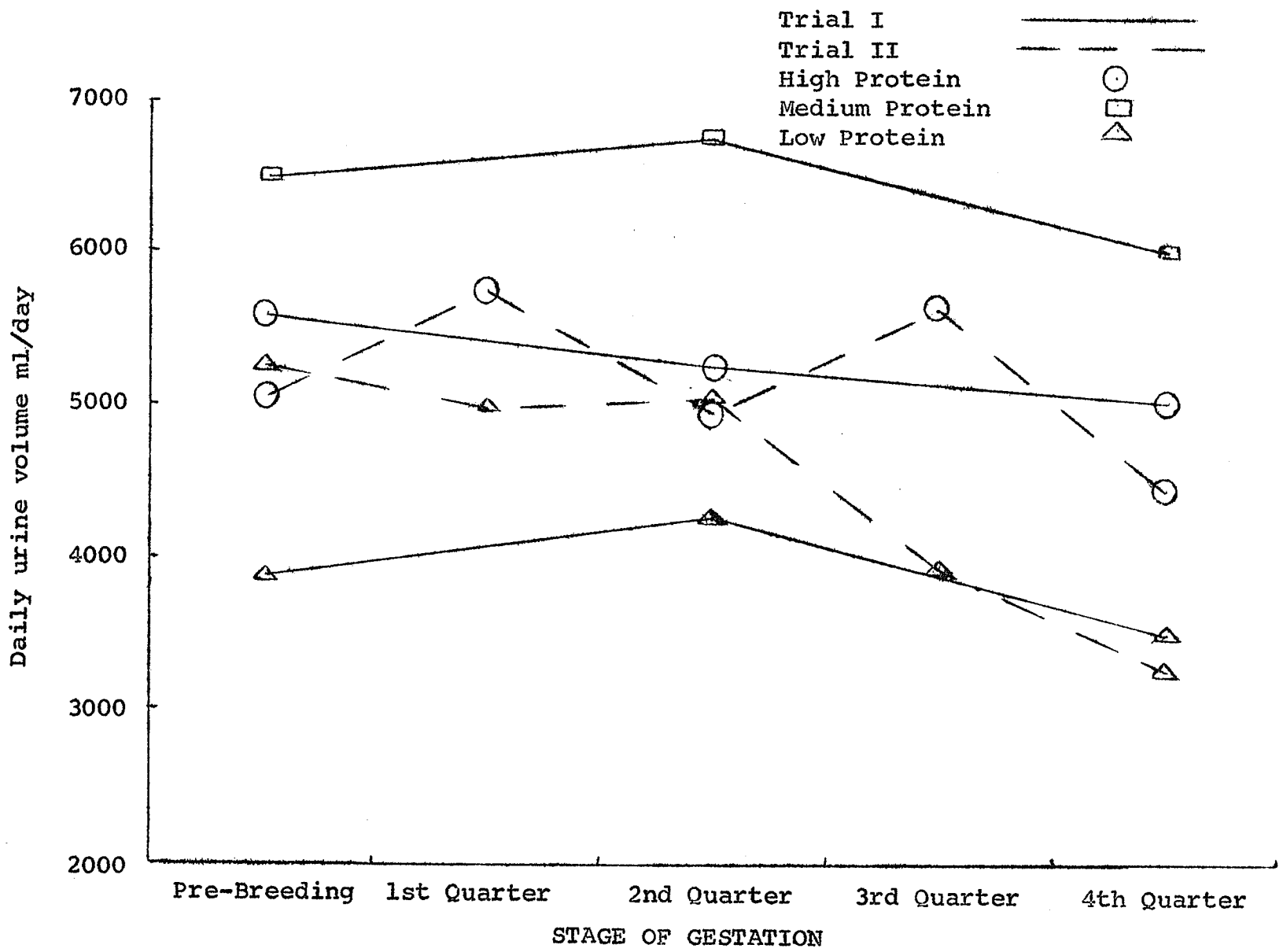


FIGURE VI

AVERAGE URINE VOLUME PREBREEDING AND IN GESTATION



URINARY CREATINE, CREATININE AND TOTAL CREATINE-CREATININE

Creatine, creatinine and total creatine-creatinine levels in urine were only determined in Trial II and the results obtained were fairly consistent for individuals in a particular period of gestation (Table XVII) (Figure VII).

Animals receiving the high protein ration showed early increments in creatinine excretion with a slow fall occurring in the latter stages of gestation. Creatine and total creatine-creatinine levels showed increments from pre-breeding to parturition.

For both the high protein and low protein treatments significant differences were not obtained in levels of creatine, creatinine and total creatine-creatinine excreted either between treatments or at the various stages of gestation investigated.

On considering the values obtained for animals receiving the low protein ration a continual fall in the level of urinary creatinine occurred from pre-breeding to parturition.

The change in creatinine excretion levels from pre-breeding to the first quarter of gestation is difficult to interpret, as excretion levels on the high protein ration showed a marked rise whereas animals on the low protein treatment showed the reverse. However, from the first quarter of gestation to parturition the excretion levels followed a very

TABLE XVII

$\bar{X}$ CREATINE, CREATININE AND TOTAL CREATINE-CREATININE EXCRETION LEVELS (GM/DAY) AND CREATININE COEFFICIENTS IN GESTATION

Ration	Type of Detm.	Pre-Breeding	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
High Protein	Creatinine	0.709±0.117[2] (6)[1]	0.925±0.290 (9)	0.889±0.251 (11)	0.918±0.127 (11)	0.831±0.270 (12)
	Creatine	0.108±0.064 (6)	0.114±0.079 (9)	0.155±0.104 (11)	0.230±0.163 (11)	0.278±0.189 (12)
	Total Creatine+Cr	0.817±0.143 (6)	1.039±0.269 (9)	1.043±0.309 (11)	1.148±0.168 (11)	1.169±0.310 (12)
	Creatinine Coefficient	4.295±0.687 (6)	5.216±1.350 (9)	4.553±1.101 (11)	4.190±0.527 (11)	3.918±0.923 (12)
Low Protein	Creatinine	0.866±0.128 (6)	0.816±0.175 (9)	0.722±0.192 (8)	0.750±0.139 (10)	0.683±0.104 (14)
	Creatine	0.239±0.064 (6)	0.113±0.079 (9)	0.110±0.010 (8)	0.131±0.160 (10)	0.133±0.189 (14)
	Total Creatine+Cr	1.105±0.196 (6)	0.929±0.231 (9)	0.832±0.488 (8)	0.881±0.214 (10)	0.816±0.177 (14)
	Creatinine Coefficient	5.026±0.946 (6)	4.296±0.811 (9)	4.096±0.905 (8)	3.438±0.688 (10)	3.368±0.475 (14)

[1] No. of determinations.

[2] Standard errors.

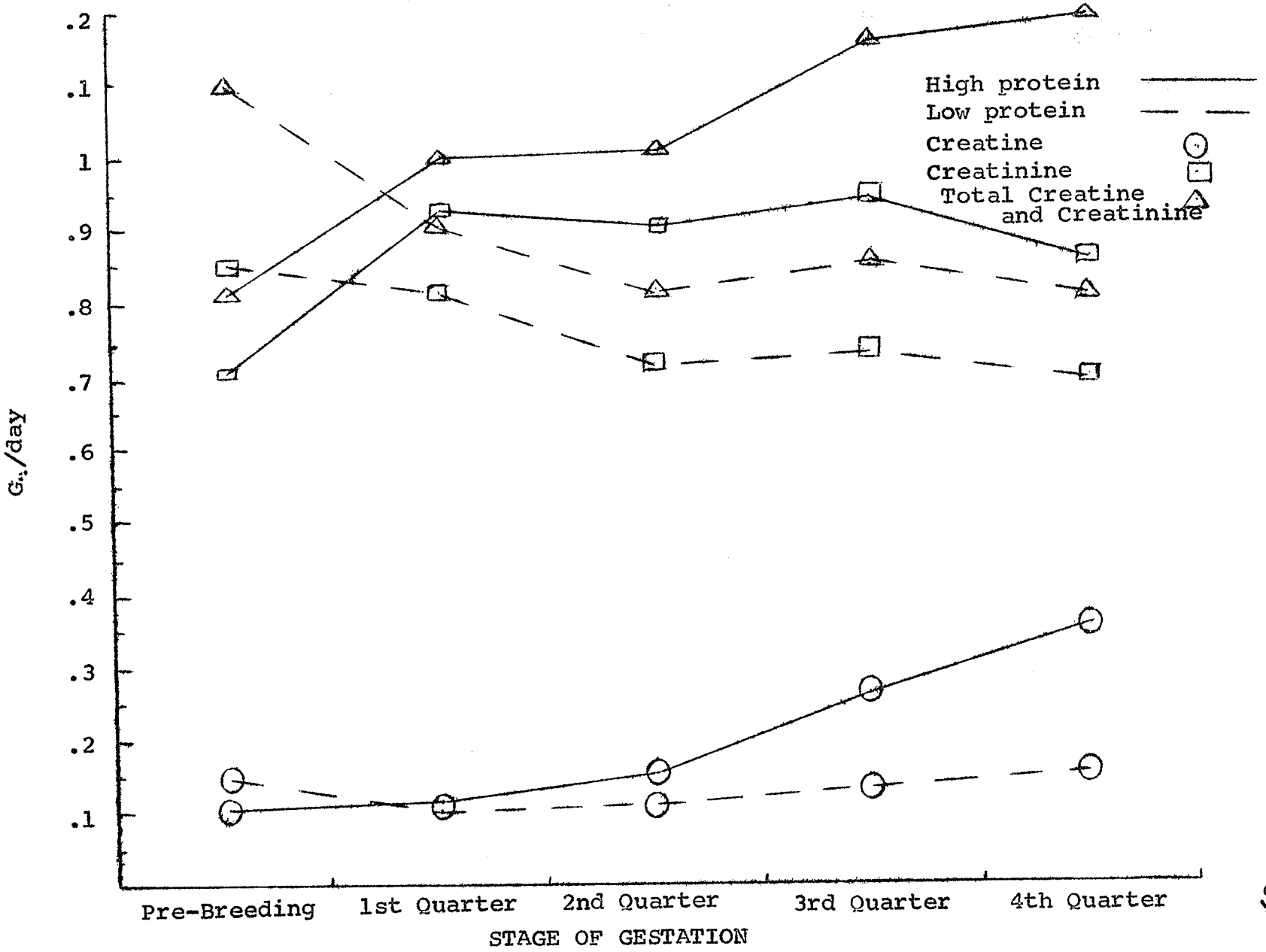
similar pattern for both treatments.

Considering the work of Saffle et al. (1958) and Van Niekerk (1963), high correlations between daily levels of creatinine excretion and body protein contents should exist. As fourth quarter gestation values for the high protein treatment were higher than pre-breeding values a net increment in body protein would be indicated. However the low protein treatment animals showed a considerable fall suggesting that a net loss of protein may have occurred in gestation. Due to the increments in weight and positive nitrogen balances observed in these animals during this period, the above deduction is not acceptable.

A possible contributing factor to this observed fall in creatinine excretion could arise from the body of information which suggests a mammal is capable of utilizing some of its own body protein to reproduce if nutrient levels in gestation are poor. This information is well summarized by Mitchell (1962). A situation of this nature may have arisen in the animals receiving the low protein ration, with the result that quantities of amino acids from the breakdown of maternal body protein would be used for synthesis of fetal protein. Now these amino acids derived and utilized by the animal for fetal synthesis would generally speaking be the essential amino acids which include methionine and arginine. As a result these amino acids would not be available for

FIGURE VII

CREATINE, CREATININE AND TOTAL CREATINE CREATININE
PREBREEDING AND IN GESTATION



creatinine formation and a fall in excretion levels would occur.

Creatinine Coefficient

Saffle et al. (1958) found for growing swine a high positive correlation between the creatinine coefficient and lean contents of individual tissues.

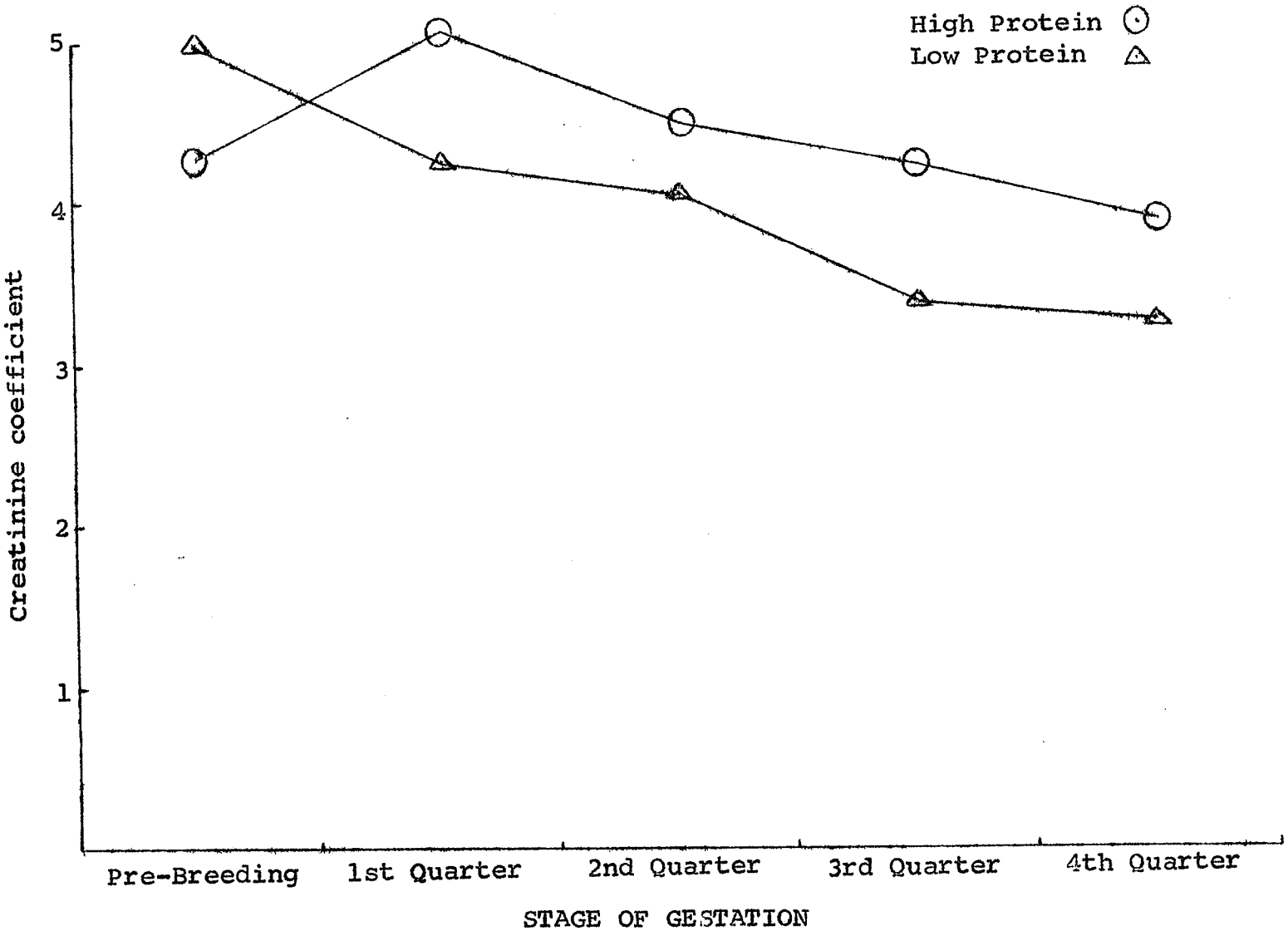
As would be expected, on examining this factor no significant differences between the two groups of animals prior to breeding occurred. However, in both groups a significant fall in the creatinine coefficient occurred from pre-breeding to the fourth quarter of gestation, with the fall being significant at the five per cent level for the high protein treatment and the one per cent level for the low protein animals, (Table XVII) (Figure VIII).

Despite the considerable changes in creatinine coefficient rated in the fourth treatment, statistically significant differences were not obtained either between treatments or between the different stages of gestation investigated.

On both treatments the fall in creatinine coefficient suggests the percentage of lean meat in the animals is falling, but a net increment in total protein content would still be possible due to the large increment in weight during gestation.

FIGURE VIII

CREATININE COEFFICIENT PREBREEDING AND IN GESTATION



Two factors which could combine to emphasize this fall in creatinine coefficient are the reutilization of amino acids as suggested before and a possible oedematous condition which could occur as parturition approaches. In the case of the latter an increasing water percentage in mammary tissues and the uterus would bring about a decrease in creatinine coefficient.

Blood Studies

Due to the fact that no significant differences could be detected in the blood studies to be discussed, the data in Trial I are presented in a combined form as high, medium and low protein treatments only.

Red Cell Counts

The variation in red blood cell counts was fairly large ranging from four to eight million per mm^3. However, the average of a group at a particular stage of gestation fell within the range of 4.5 to 6.5 million cells per mm^3. These data are presented in Table XVIII and it is easily seen that no obvious trend in red cell numbers occurred as gestation progressed, though values tended to fall just prior to parturition.

Haematocrit

Haemotocrit values were fairly consistent through-

out but showed a definite tendency to fall as parturition approached. The mean haematocrit data are presented in Table XIX. Statistical differences could not be detected due to high variability between animals and the small sample size. However, the fall in haematocrit values prior to parturition was consistent for all animals.

Haemoglobin Determinations

These data are presented in Table XX and though values for an individual were fairly consistent the standard error was such that only in the medium protein ration of Trial I could a statistically significant fall ($P<0.05$) be detected when comparing pre-breeding values to the fourteenth week of gestation.

The values obtained in this experiment for red cell count, haematocrit and haemoglobin compare favourably to data presented by Miller *et al.* (1961) who also found that these criteria had a tendency to decline as gestation progressed. This is thought to be a manifestation of 'pseudo-anemia', a condition occurring in the human as parturition approaches and caused by hemo-dilution.

White Cell Counts

These data are presented in Table XXI. The values obtained ranged from 9,700 to 21,900 cells per mm^3. When

TABLE XVIII

$\overline{X}$ RED CELL COUNT AT VARIOUS STAGES OF GESTATION (THOU/CU MM)

Trial I Ration	Pre-Breeding	Stage of Gestation				Post Farrowing
		3 Weeks	6 Weeks	11 Weeks	14 Weeks	
High Protein	6111 ±175[2] (9)[1]	6600± 421	6483	6535±221	5871±189	5688± 389
Medium Protein	5860 ±197 (2)	5605	5710	5640±	5665±558	6775± 295
Low Protein	6370 ±522 (2)	6965± 657	7020	6900±642	6320±537	6120±1153
Low Protein Barren Animals	6324	6696	6476	6372	5926	6225
Trial II						
High Protein	5325 ±276 (6)	5645± 333	--	4695±542	5106±391	5375± 528
Low Protein	6327*±695 (6)	6270±1099	--	5973±278	5560±532	5615± 481

*4 Determinations only.
[1]No. of determinations.
[2]Standard error.

TABLE XIX

$\bar{X}$ HAEMATOCRIT VALUES AT VARIOUS STAGES OF GESTATION (%)

Trial I Ration	Pre-Breeding	Stage of Gestation				Post Farrowing
		3 Weeks	6 Weeks	11 Weeks	14 Weeks	
N.R.C. Standard Protein	38.2 ±3.88[2] (9)[1]	39.4 ±3.90	38.7	39.8 ±4.1	36.75±2.24	39.0 ±4.6
Medium Protein	36.0 (2)	40.0 ±1	40.5	38.5 ±1	35.5 ±2.24	39.0 ±2.8
Low Protein	39.25±1.41 (2)	42.0 ±4.0	40.0	39.5 ±2.2	35.25±2.82	39.0 ±1.41
Barren Sows Low Protein	38.0 (6)	38.0	40.0	39.5	38.5	41.5
Trial II						
N.R.C. Standard Protein	36.5 ±2.45 (6)	37.83±2.8	--	37.17±3.3	33.48±2.68	36.75±3.25
Low Protein	37.58±3.5 (6)	40.0 ±6.0	--	39.83±5.0	32.25±5.6	38.10±8.5

[1] No. of determinations.
[2] Standard errors.

TABLE XX

$\overline{X}$ HAEMOGLOBIN VALUES AT VARIOUS STAGES OF GESTATION - G./100 ML

Trial I Ration	Pre-Breeding	Stage of Gestation				Post Farrowing
		3 Weeks	6 Weeks	11 Weeks	14 Weeks	
N.R.C.Standard	13.0 ±1.36[2] (9)[1]	13.2 ±1.50	13.1	12.3 ± .87	11.2 ±1.58	12.30±1.37
Medium Protein	11.0 ±1.00 (2)	15.5 ±1.16	14.0	15.0 ±1.20	11.0 ±1.00	12.0 ±1.49
Low Protein	13.5 ±1.00 (2)	13.5 ±1.31	12.0	12.80±1.10	12.0 ±2.00	12.80±2.15
Barren Sows Low Protein	13.0 ± (6)	12	12.0	12.0	12.6	13.0
Trial II						
N.R.C.Standard Protein	10.80±1.00 (6)	11.87±1.00	--	12.00±0.77	10.70±0.89	11.10±0.63
Low Protein	11.20±1.61 (6)	12.30±1.2	--	12.50±1.26	10.30±1.2	10.80±0.71

[1] No. of determinations.
[2] Standard errors.

TABLE XXI

$\bar{X}$ WHITE CELL COUNT AT VARIOUS STAGES OF GESTATION NOS/CU MM

Trial I Ration	Pre Breeding	Stage of Gestation				Post Farrowing
		3 Weeks	6 Weeks	11 Weeks	14 Weeks	
N.R.C.Standard Protein	14,800±1520[2] (9)[1]	13,460±1750	14,630	13,383±3067	12,420±2517	13,235±1532
Medium Protein	10,900± 560 (2)	12,600±1023	11,850	11,000±5041	13,500±1006	19,300± 300
Low Protein	18,800±2300 (2)	18,150±2025	17,350	16,050±2170	12,900±1780	17,500±6970
Barren Sows Low Protein	13,260	13,940	12,740	12,800	12,060	14,300
Trial II						
N.R.C.Standard Protein	14,630±4024 (6)	17,010±2045	--	15,110±3309	14,080±2756	13,900±1067
Low Protein	15,900*±2645 (6)	17,016±2165	--	16,700±1997	14,633±1542	14,950*± 698

*4 Determinations only.
[1] No. of determinations.
[2] Standard errors.

considering the mean values for the various treatments no obvious trend as gestation progressed could be detected and no significant effect of protein level on white cell numbers was observed.

Total Serum Protein, Albumin and Globulin Levels (g. %)

These data are presented in Tables XXII, XXIII and XXIV respectively. Total serum protein levels proved quite variable, the values ranging from 6.5 to 9.1 g. per cent although the mean values were very similar to mean values obtained by Miller et al. (1961). In all treatments, in both trials, a tendency for total serum proteins to fall as parturition approached was noticed.

The low protein treatment animals in Trial II showed a significant fall ($P < 0.01$) in total serum protein levels from the pre-breeding stage to just prior to farrowing. This fall may be the result of two stresses, one the low level of dietary protein and the other, the high fetal demands for protein as parturition approaches. These two factors in combination with hemo-dilution tendencies at this stage of gestation would cause the significant fall in total serum protein levels noted.

As regards albumin and globulin levels in gestation, variation in results was so great and separation of the globulin fractions in the electrophoretic process so poor,

that only total albumin and total globulin fractions are presented. No significant differences could be detected because of the high standard errors.

Mean albumin levels (Table XXIII) obtained are very similar to values presented by Miller et al. (1961) for they ranged from 2.4 to 3.9 g. per cent. In all cases a tendency to fall as parturition approached occurred and post-farrowing data did not show a rapid recovery.

Total serum globulin levels (Table XXIV) remained fairly constant throughout gestation ranging from 3.3 g. per cent to 5 g. per cent despite hemo-dilution and falling serum protein levels. Thus, a net increase in the serum globulins as a percentage of total serum proteins occurred. This pattern of events ties in well with observations made by Smith et al. (1959) and Reboud et al. (1963), who working with humans observed a similar fall in albumin levels simultaneously with an increase in the globulin fractions as gestation progressed.

This situation could well explain the previously suggested occurrence of hemo-dilution, as the globulin protein molecules are generally smaller than albumin protein molecules on a molecular weight basis. Therefore, as gestation progresses larger albumin molecules are replaced by increased numbers of smaller globulin molecules. A resultant increase in osmotic pressure of the blood serum would then occur so

TABLE XXII

$\bar{X}$ TOTAL SERUM PROTEINS (G.%)

Treatment	Pre-Breeding	3 Weeks	6 Weeks	11 Weeks	14 Weeks	Post Farrowing
High Protein	7.70±.65[2] (9)[1]	7.77±.86	7.75	7.75±.93	7.31±.77	7.37±1.22
Medium Protein	7.33±.27 (2)	7.64±.12	7.46	7.64±.36	6.70±.83	6.83±.57
Low Protein	8.00±.81 (2)	7.87±.70	7.53	7.74±.36	7.24±.10	8.75±.61
High Protein	7.73±.85 (6)	8.19±.55	--	7.91±.77	7.21±.86	7.38±.60
Low Protein	8.10±.79 (6)	7.80±.77	--	7.48±.70	6.86±.71	7.29±.59

[1]No. of determinations.

[2]Standard errors.

TABLE XXIII

$\bar{X}$ ALBUMIN LEVELS AT VARIOUS STAGES OF GESTATION (G.%)

Treatment	No. Involved	Pre-Breeding	3 Weeks	6 Weeks	11 Weeks	14 Weeks	Post Farrowing
High Protein	9	3.87±.35[1]	3.72±.29	3.45±.31	3.62±.23	3.73±.31	3.45±.27
Medium Protein	2	3.59±.31	3.67±.36	4.03±.34	3.97±.21	2.88±.30	3.28±.26
Low Protein	2	3.36±.28	2.67±.26	3.31±.33	3.17±.40	2.97±.19	4.20±.22
High Protein	6	2.89±.23	3.32±.28	-	3.26±.18	2.90±.20	2.46±.23
Low Protein	6	3.07±.24	2.99±.15	-	2.60±.14	2.03±.05	2.35±.09

[1]Standard errors.

TABLE XXIV

$\bar{X}$ GLOBULIN VALUES AT VARIOUS STAGES OF GESTATION (G.%)

Treatment	No. Involved	Pre-Breeding	3 Weeks	6 Weeks	11 Weeks	14 Weeks	Post Farrowing
High Protein	9	3.83±.38[1]	4.05±.34	4.30±.23	4.13±.28	3.58±.36	3.92±.30
Medium Protein	2	3.74±.29	3.97±.35	3.42±.31	3.67±.37	3.82±.40	3.28±.34
Low Protein	2	4.64±.41	5.19±.42	4.22±.37	4.57±.45	4.27±.38	4.55±.36
High Protein	6	4.83±.31	4.86±.41	-	4.65±.25	4.31±.29	4.92±.44
Medium Protein	6	5.03±.38	4.81±.24	-	4.88±.26	4.83±.13	4.94±.18

[1]Standard errors.

that more water would move into the blood causing increased blood volume and hemo-dilution.

Number of Pigs Born

In Trial I there were no significant differences in the total number of pigs born or the total number of live born pigs when comparing the high and medium protein treatments, although the high protein treatment farrowed 1.7 more live pigs than the medium protein animals (Table XXV). The low protein treatment however, presented a different picture for significantly fewer pigs were born and all were still-born. Again no differences in the number of still-born pigs existed between high and medium protein treatments but a significantly higher number of still-born pigs occurred on the low protein treatment. In the light of data obtained in Trial II no explanation can be offered as to why no live young were produced on this treatment in Trial I.

When comparing the above results with those obtained in Trial II, little similarity exists as no significant differences in total numbers born, the number born alive, or the number of still-born could be detected. It should be mentioned that one sow on the low protein ration farrowed unexpectedly and five of her young were dead. Whether these were still-born or died in the fetal membranes is not known. This contributed to the result that animals receiving the

low protein treatment farrowed 0.83 more still-born pigs and 2.34 fewer live pigs per litter.

Pig Birth Weights

The mean litter and pig birth weights are presented in Table XXV. In Trial I no significant differences in total litter and average pig birth weights could be detected when comparing the medium and high protein rations. Despite animals on the medium protein ration farrowing slightly heavier pigs, the fewer numbers resulted in lower total litter weights. The same pattern was repeated in the figures for live born pigs.

Total litter weight and mean pig weight for animals receiving the low protein treatment were significantly lower than for animals receiving the medium and high protein treatments.

In Trial II the low protein animals farrowed approximately four pounds less per litter but mean birth weights were slightly higher. For live pigs the high protein treatment farrowed seven pounds more per litter but mean birth weights for pigs were slightly less than the low protein treatment. However, no statistically significant differences could be detected between high and low protein treatments for total litter weight and mean birth weight or for total live litter weights and mean live birth weights.

TABLE XXV

NUMBERS OF YOUNG BORN AND MEAN PIG BIRTH WEIGHTS

Treatment	Total Born	Still Born	Born Alive	Total Born		Born Alive	
				Litter B Wt	Pig B Wt	Litter B Wt	Pig B Wt
Trial I							
High Protein	11.6±3.57[2] (9)[1]	1.33±2.98	10.2±5.14	29.6±12.1	2.56±0.79	27.33±14.1	2.67±0.53
Medium Protein	9.5±1.00 (2)	1.00±1.41	8.5±2.23	26.4± 7.9	2.77±0.65	24.05±12.0	2.83±0.67
Low Protein	5.5±5.00 (2)	5.5 ±5.00	0	8.8±6.8	1.60±0.36	0	0
Trial II							
High Protein	11.0±3.31 (6)	1.0 ±1.17	10.0±3.38	32.8± 6.35	2.98±0.60	30.35± 7.4	3.04±0.58
Low Protein	9.5±3.19 (9)	1.83±1.61	7.7±2.19	28.2± 9.53	3.07±0.65	23.8± 4.4	3.10±0.79

[1]No. of determinations.
[2]Standard errors.

LACTATION STUDIES

It is of importance to note that all animals received the high protein ration in lactation regardless of gestation ration. In this section effects on the young as well as the sow have to be considered.

Survival Data

These data are presented in Table XXVI. In Trial I few comparisons can be made from the data due to the limited numbers on the medium and low protein rations. The lower survival rates on the medium protein ration could well be due to the fact that the pigs from the one sow considered were badly chilled at birth. A second sow to farrow on this treatment developed agalactia and severe mastitis with the result that her pigs were then transferred to another sow. These data were then eliminated.

In Trial II the high protein treatment animals raised 1.5 more pigs to one week of age but this was not significant. It should be noted that the one week data on one high protein treatment animal was eliminated, as she would not suckle the pigs and they had to be put on milk replacer. The percentage survival of total numbers born was almost identical but the survival percentage of numbers born alive was six per cent higher for the low protein animals.

TABLE XXVI

BABY PIG SURVIVAL AT ONE AND THREE WEEKS

Treatment	No. of Litters	Total No. 1 Wk	Total No. 3 Wk	Av/Litter 1 Wk	Av/Litter 3 Wk	% Survival Of Total Born 1 Wk	% Survival Of Total Born 3 Wk	% Survival Of Total Born Alive 1 Wk	% Survival Of Total Born Alive 3 Wk
Trial I									
High Protein	7	70	67	10.0 ±1.73[1]	9.6±1.63	82.4	78.8	86.4	82.7
Medium Protein	1	7	6	7	6.0	70.0	60.0	70.0	60.0
Low Protein	0	0	0	0	0	0	0	0	0
Trial II									
High Protein	3	28	27	9.3±1.0	9.0±2	71.8	69.2	84.8	81.8
Low Protein	4	31	30	7.8±2.12	7.5±1	72.1	69.8	91.2	88.2

[1]Standard errors.

Pig survival data to three weeks presents a very similar picture. In Trial I the higher survival rate for the high protein animals was maintained as some 3.6 more pigs were raised per litter. In Trial II the high protein animals again raised 1.5 more pigs per litter than the low protein treatment animals. Percentage survival rates of total numbers born were again identical, but the low protein treatment animals maintained a six per cent higher survival rate when expressed as a percentage of live born young. This suggests that the low protein treatment animals farrowed fewer but stronger young or the sows showed better mothering qualities in lactation than the high protein treatment animals. However, another factor which may be of greater importance is that the low protein sows were suckling fewer young, with the result that more milk was available to the young. This might well have resulted in a higher survival rate.

Post mortem examinations were performed on all young which died during the lactation period with the result that no specific cause of death other than crushing or starvation could be diagnosed. Thus, differences in survival rates could not be related to the gestation rations.

Mean One Week and Three Week Pig and Litter Weights

Data at the one week stage of lactation were only collected in Trial II and are presented with the three week

TABLE XXVIa

$\bar{X}$ PIG AND LITTER WEIGHTS AND RELATED BALANCE TRIAL DATA

Treatment	No. of Litters	$\bar{X}$ Total Litter Weight	$\bar{X}$ Pig Weight	Milk/Pig /Day (g.)	Protein Received /Pig/Day (g.)	Sow's Feed Consumption in Balance Trial
			$\bar{X}$ ONE WEEK DATA (LB.)			
Trial II						
High Protein	3	45.83± 6.56[1]	4.90±1.1	439 ±228	38.6±17.5	5.26±2.4
Low Protein	4	40.10± 6.24	5.20±1.8	416[2] ±160	25.4[2]±13.1	5.26[2]±1.1
			$\bar{X}$ THREE WEEK DATA (LB.)			
Trial I						
High Protein	8	89.80±37.5	10.12±3.1	389 ±231	25.1±26.5	10.40±2.0
Medium Protein	1	64.8	10.80±0.9	472 ±190	25.3±21.6	11.50
Trial II						
High Protein	3	78.5 ±13.5	8.70±2.0	493 ±358	22.6±40.0	5.66±1.3
Low Protein	4	51.1 ±14.5	6.80±1.8	390 ±266	17.7±12.7	5.03±2.0

[1]Standard error of the mean.

[2]Due to the poor condition of one litter, no balance trial was conducted at one week for this sow and litter.

weights, daily milk and milk protein levels and sows' feed consumption in the lactation balance trials (Table XXVIa).

At the one week stage of lactation, little difference in either total litter weight or mean pig weight occurred, the high protein treatment sows having litters six pounds heavier and piglets 0.3 lb. lighter than the low protein treatment sows.

At the three week stage of lactation in Trial I, the average total litter weight of the high protein treatment animals was twenty-five pounds heavier than the medium protein treatment. In Trial II the average litter weight of the low protein treatment was twenty-seven pounds lighter than the high protein treatment. The difference in Trial II was statistically significant ($P < 0.05$).

The average weights of pigs for the two treatments in Trial I were almost identical, but in Trial II the piglets of the high protein treatment were two pounds heavier than those from the low protein treatment animals. This difference was statistically significant ($P < 0.01$). A combination of lower numbers raised to three weeks and lighter young of the low protein treatment animals resulted in the large difference in total litter weight noted.

It will be noticed that the three week weights (Table XXVIa) of the animals in Trial II are considerably lower than those in Trial I. Generally a three week weight of

approximately ten pounds is considered acceptable. Thus, the three week weights of Trial I are reasonable and the one week weights in Trial II may be considered average. However, the three week weights in Trial II are below average and difficult to explain, especially for the low protein treatment.

A factor which might be considered to explain these results is the daily feed consumption of the animals during lactation. It is possible that low feed consumption would result in lower milk production and vice versa. In contrast to Trial I, in Trial II considerable difficulty was encountered in persuading the sows to eat regardless of the gestation ration with the result that overall feed consumption levels were approximately half those in Trial I. With the exception of the low protein animals in Trial II, feed consumptions during balance trials were similar to those noted in the lactation period.

Despite the failure to eat during lactation in Trial II, based on the balance trial data the quantities of milk received per day by the young of all treatments in both Trial I and Trial II are very similar. However, based on information summarized by Duncan and Lodge (1960), errors in estimation of total milk yield may have been considerably higher in Trial I as compared to Trial II. The reason for this is that significant falls in milk production by lactating

sows may occur by the second day of a lactation balance trial period. Thus in the four day trial system used in Trial I a considerable fall in milk production could have occurred by the fourth day in comparison to the two day trials conducted in Trial II. Therefore, the quantity of milk received by the young in Trial I may well have been higher than the estimates obtained from the lactation balance trials. Based on data summarized by Duncan and Lodge (1960) milk yield was found to be stimulated by stronger and healthier pigs. The young of the sows in Trial II suffered from severe scour conditions with resultant loss of weight and vigor, so their ability to stimulate the sow's milk production by robust suckling would be curtailed in comparison to the young of sows in Trial I.

The quantity of milk protein received by the young in Trial I and Trial II is very similar except in the case of the low protein treatment in Trial II where a significantly lower ($P < 0.01$) quantity of milk protein was received at the one week stage of lactation by the young of this treatment. The level of milk protein received by the young of the low protein treatment sows was again lower at the three week stage of lactation but statistical significance was not achieved ($P > 0.05$). The lower levels of milk protein received by the young of the low protein treatment sows would in part account for the lower three week weights noted for this treatment

group. However it should be noted that the lower three week weights of the young of the high protein treatment in Trial II as compared to Trial I can be partially attributed to a higher incidence of scours during the lactation period in Trial II. Scouring could also have contributed to the lower three week weight of the young of the low protein treatment animals in Trial II.

The protein content of the milk from individual teats was variable. However, both the high protein and low protein treatments showed a significant fall in milk protein content from the first to the third week of lactations. Milk from the high protein treatment sows showed a fall in protein content from 8.55% ± 2.24 to 4.85% ± 1.97 in comparison to the low protein treatment where the fall was from 6.08% ± .82 to 4.46% ± 1.56. The protein content of the milk from the high protein treatment sows at the one week stage of lactation was significantly higher ($P < 0.01$) than that of the low protein treatment sows. No statistically significant difference in milk protein content could be detected between the two treatments at the three week stage of lactation.

In general, the data on milk yield and milk composition obtained in this experiment compare favorably with data reviewed by Duncan and Lodge (1960). Mean daily milk and milk protein in grams per day supplied to the young by sows in these trials were equivalent to estimates made by

other workers using similar balance trial procedures. However, it should be noted in Trial II that the milk yield of the sows did not increase to any extent from the first week to the third week of lactation. This is not in agreement with the data presented by Duncan and Lodge (1960) which indicated a marked increase in milk yield over this period. Scouring conditions, a lack of vigorous suckling and low feed consumption of the sows are interrelated factors already discussed which should account for much of this lack of agreement.

Sow Body Weight Losses and Daily Feed Consumption During Lactation

Body weight losses by sows in the first three weeks of lactation were variable, especially in Trial I. These data and the feed consumption data are presented in Table XXVII.

The high protein animals in Trial I lost 21.7 lb. in the first week of lactation and 37.0 lb. in the two weeks following, giving a total loss of nearly 59.0 lb. This is considerably higher than the medium protein animals in Trial I and is also higher than either the high or low protein treatments in Trial II.

In Trial II the high protein treatment sows lost weight steadily throughout gestation whereas the low protein animals showed a markedly higher loss in the first week of gestation in comparison to that lost from seven to twenty-one

TABLE XXVII

$\bar{X}$ BODY WEIGHT LOSS AND $\bar{X}$ DAILY FEED CONSUMPTION

OF SOWS DURING LACTATION (LB)

Treatment	No. of Detm.	Loss of Weight 0-7 Days	Average Daily Feed 0-7 Days	Loss of Weight 7-21 Days	Average Daily Feed 7-21 Days	Loss of Weight 0-21 Days	Average Daily Feed 0-21 Days
Trial I							
High Protein	8	21.7±25.9[1]	8.44±1.61	37.0±18.3	10.9±2.61	58.7	10.4
Medium Protein	1	-	11.50 -	1.0 -	11.5 -	1.0	11.5
Trial II							
High Protein	3	15.0±13.8	5.26±1.12	32.0±14.7	5.8±1.0	47.0	5.6
Low Protein	3	21.5± 4.8	5.8 ±1.5	7.5± 9	8.1±2.0	29.0	7.3

[1] Standard errors.

days. This difference was not statistically significant ($P > 0.05$). It is of interest to note that the greater weight losses throughout lactation of the high protein sows in comparison with low protein sows coincide with the lower feed consumption levels during lactation.

As already noted the high protein sows produced more milk during lactation and weaned heavier pigs, so that their greater weight losses are explained.

Lactation Balance Trial Data

In Trial II of this experiment lactation balance trials were conducted at one week of age and three weeks of age on three litters from the animals receiving the high protein ration in gestation and four litters from sows receiving the low protein ration in gestation. Lactation balance studies in Trial I were conducted only at the three week stage.

Few comparisons can be made from lactation data obtained in Trial I as only one trial was conducted on medium protein treatment animals and eight trials on the high protein treatment animals.

Feed consumption of the animals in Trial I during the lactation period was considerably higher than in Trial II (Table XXVIII) and with this considerably higher feed consumption in Trial I positive nitrogen balances at the three

week stage of gestation were noted whereas in Trial II at this same stage negative nitrogen balances occurred.

Digestibilities as determined on the basis of chromium oxide marker were variable. Some of the variability could have been due to the animals eating bedding straw, but in the last eight trials no bedding was supplied and the same variability occurred. There was a tendency for animals consuming the higher levels of feed to have lower digestibility coefficients.

As noted in the discussion on protein retentions, the high protein animals, after allowing for losses of protein at parturition, apparently had body stores remaining of some 12,500 g. of protein. Similarly, the low protein animals had body stores of 1,700 g. With milk production and body weight losses during lactation their reserve would be utilized.

In Trial II it will be noted that animals from both high and low protein treatments, both of whom received the high protein ration in lactation, showed marked negative balances at the sixth and seventh day. This is in keeping with the work of Lenkeit (1956) who discovered that in the first ten days after parturition considerable losses of nitrogen occurred.

Assuming negative nitrogen balances of this magnitude occurred for the first ten days of lactation animals

on the high protein treatment would lose some 3,800 g. of protein while those on the low protein treatment in gestation would lose 490 g. of protein.

Considering the data in Table XXVIII, if the high protein treatment animals lost 3,800 g. of protein in the first ten days of lactation and if losses for the next eleven days are taken as -102 g. of protein per day, a further 1,100 g. of protein would be lost. In total 4,900 g. of protein would be lost to the twenty-first day of lactation. This still leaves an extra retention of some 7,600 g. of protein. Further losses of protein are likely to occur in the last three weeks of lactation thus if 102 g. per day are lost for the last twenty-one days, a further 2,142 g. would be accounted for leaving 5,480 g. of protein still to be accounted for.

Considerable weight losses occur post weaning as well as during the lactation period and negative nitrogen balances occur during this period according to Lodge *et al.* (1961) and Lenkeit *et al.* (1956). As approximately half of the extra weight gains during gestation are lost in lactation further losses could occur post weaning. A portion of the extra 5,480 g. of protein could be lost post weaning.

The low protein treatment animals had a significantly higher ($P < 0.01$) nitrogen balance early in lactation and present a somewhat different picture. Lactation losses in the

TABLE XXVIII

LACTATION BALANCE TRIAL DATA

	Gestation Treatment	No. Detm.	Feed Level lb./day	DM Digest	Crude Prot. Digest	Prot. Absorb g./day	Urine Nitrogen (g. prot/day)	Milk Protein	Total Prot. Lost	Protein Retention
	1 Week Trial									
Trial II	High Protein	3	5.26 ±2.72[1]	85 ± 5	82.0 ± 4.4	272 ± 47.3	306 ±103.0	350 ±142.0	656 ± 39.7	-382 ± 14.5
	Low Protein	3*	5.26 ±1.18	79 ± 1.6	75.5 ± 0.7	250 ± 60.0	122 ± 27.4	177 ± 29.5	299 ± 83.5	- 49 ± 32.7
	3 Week Trial									
Trial I	High Protein	8	9.40 ±1.98	87 ± 2.98	81.0 ± 5.34	500 ± 53.0	259 ± 38.91	212 ± 94.00	471 ± 93.5	+ 29 ± 62.3
	Medium Protein	1	11.50 -	89 -	74 -	557 -	180 -	151.0 -	331 -	+226 -
Trial II	High Protein	3	5.03 ±1.22	84 ± 5.3	82.0 ± 9.00	268 ± 51.7	174 ± 29.6	196 ± 90.9	370 ±165.0	102 ± 42.3
	Low Protein	4	5.66 +2.00	81 + 5.3	77.6 + 8.00	292 +157.0	253 + 79.2	130 + 81.5	383 + 87.0	-85 + 37.8

*Due to the poor condition of one litter no trial was conducted at one week.

[1]Standard errors.

first ten days would be 490 g. of protein and for the next eleven days a further 900 g. would be lost, so that a total of 1,390 g. of protein would be lost in the first twenty-one days. If this rate of loss continued for a further twenty-one days, 1,800 g. of protein would be lost, giving a total of approximately 3,200 g. or 1,500 g. in excess of the extra retentions noted in gestation. The total negative balance if one assumes a similar loss post weaning comes to 4,700 g. of protein. Such losses are bound to put a strain upon the animal's system so either higher feed or protein levels in lactation to minimize the loss or a period of recuperation post weaning would be desirable to prevent the accumulation of this deficit.

SUMMARY

The feeding of three different levels of protein in the gestation period of sows and their effects upon weight change, digestibilities, nitrogen retention, creatine and creatinine excretion levels, blood composition and reproductive performance were studied in two separate trials.

Due to fertility problems encountered in Trial I data from only a limited number of sows were obtained. This was especially applicable to the low protein ration. The problem was believed due to the use of animal tallow in Trial I, so that lard was used as a source of animal fat in Trial II.

Under the conditions of these investigations the following conclusions were reached.

1. Decreasing the levels of protein received by the sow in gestation from 420 g. per day to 170 g. per day did not significantly affect weight gains in gestation or weight losses at farrowing for animals in Trial II, though significantly lower weight gains to farrowing and losses at parturition were noted in Trial I.

2. In Trial II protein digestibilities were lower for the low protein treatment and dry matter digestibilities were higher but statistical significance was not achieved.

3. Protein retentions during gestation were significantly lower ($P < 0.01$) for animals receiving 320 g. and 170 g. of protein per day in their diet. In Trial II, marked increases in protein retention occurred immediately post-breeding with a further significant rise later in gestation for animals receiving the high protein ration.

4. The urinary creatine, creatinine and total creatine-creatinine excretion levels were not altered by the lower protein gestation diet. The creatinine coefficients of both treatments in Trial II followed the same falling trend in gestation.

5. The level of protein in the gestation diet had no effect upon red or white cell count, haematocrit, haemoglobin, serum protein, serum albumin or globulin levels during gestation.

6. In Trial II no significant changes in the weight, dry matter content or protein content of the young, afterbirth and fetal fluids occurred with the different gestation diets.

7. No significant differences ($P > 0.05$) in the number of pigs born, the number of still born or pig birth weights could be detected in Trial II. Though fewer stillbirths occurred on the high protein ration the difference was not significant ($P > 0.05$).

8. The survival rates of young to one and three weeks

of age were greater for animals on the low protein ration, tending to reduce the difference in numbers of live young at three weeks between the two treatments.

9. The lower level of protein in the gestation ration did have a significant lowering effect on the average weights of young and the total litter weight at the three week stage of lactation, although no significant differences ($P > 0.05$) could be detected at one week.

10. The young of the sows which received the low protein ration in gestation received almost identical quantities of milk as the high protein treatment but due to the lower protein content significantly less milk protein at the one week stage of gestation was received. The lower level of milk protein received at the three week stage was not significant ($P > 0.05$).

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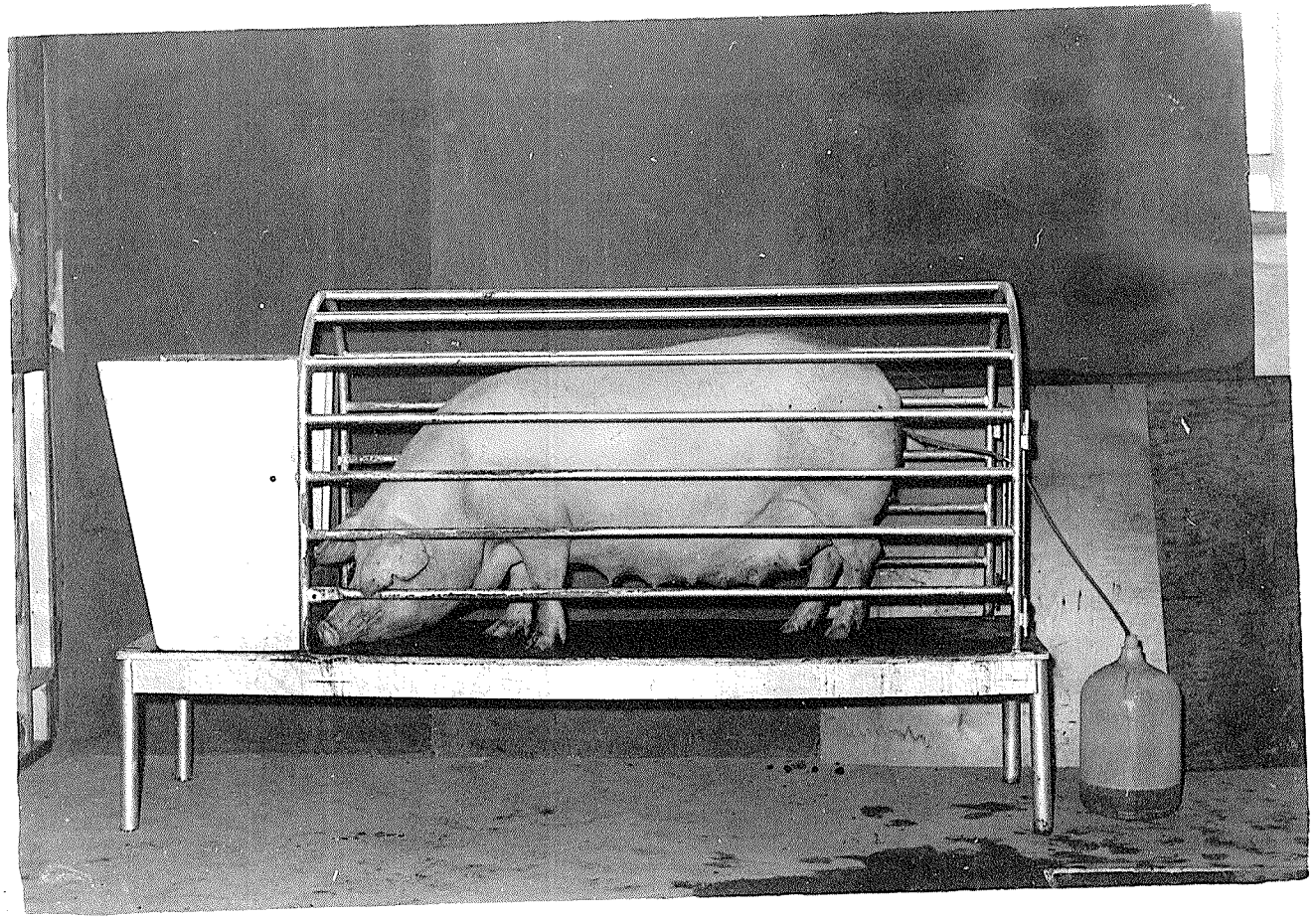
A P P E N D I X

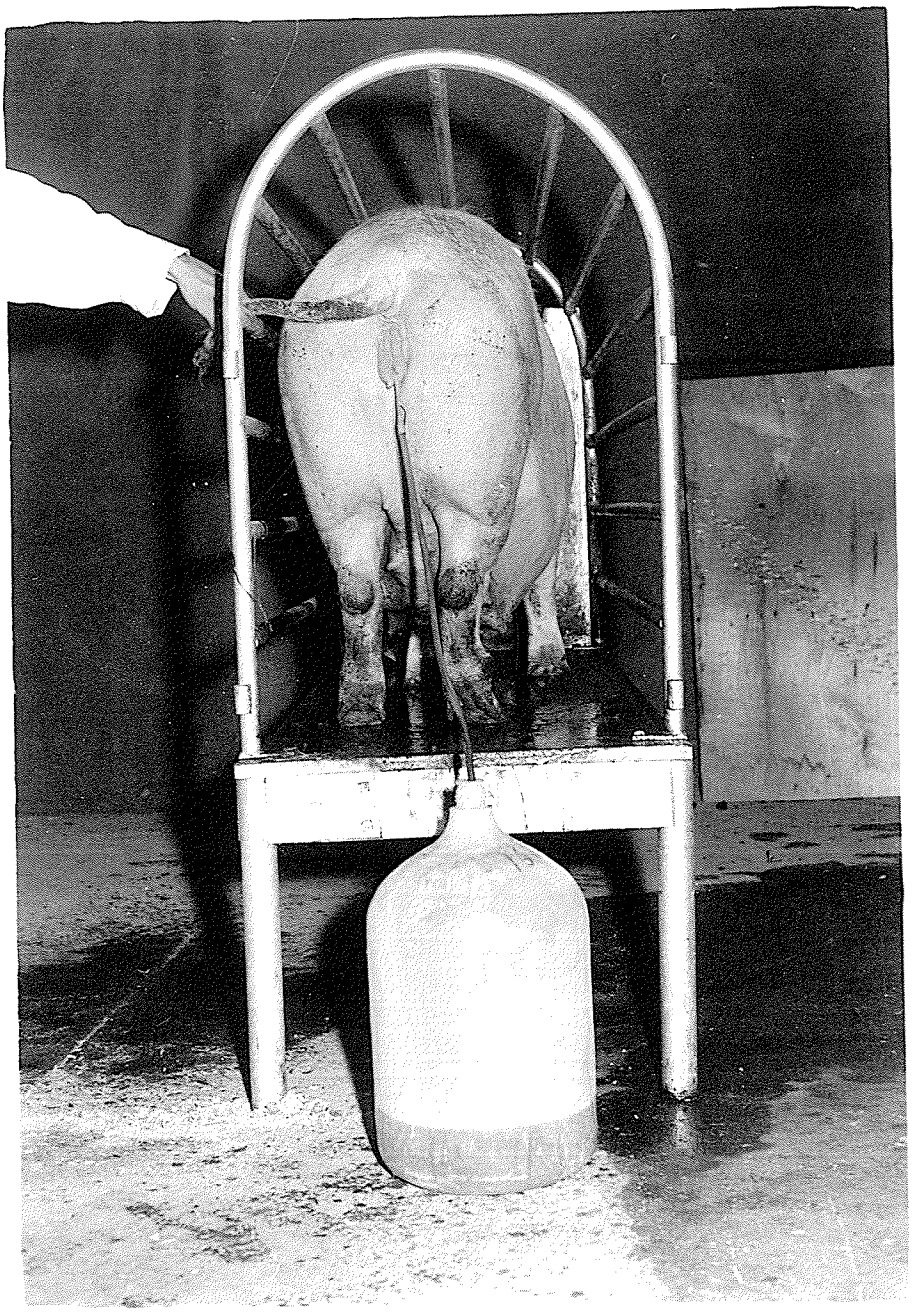
PHOTOGRAPH I



CATHETERIZED ANIMAL IN A METABOLISM CRATE

(SIDE VIEW)

PHOTOGRAPH II



CATHETERIZED ANIMAL IN A METABOLISM CRATE

(REAR VIEW)

DIAGRAM I

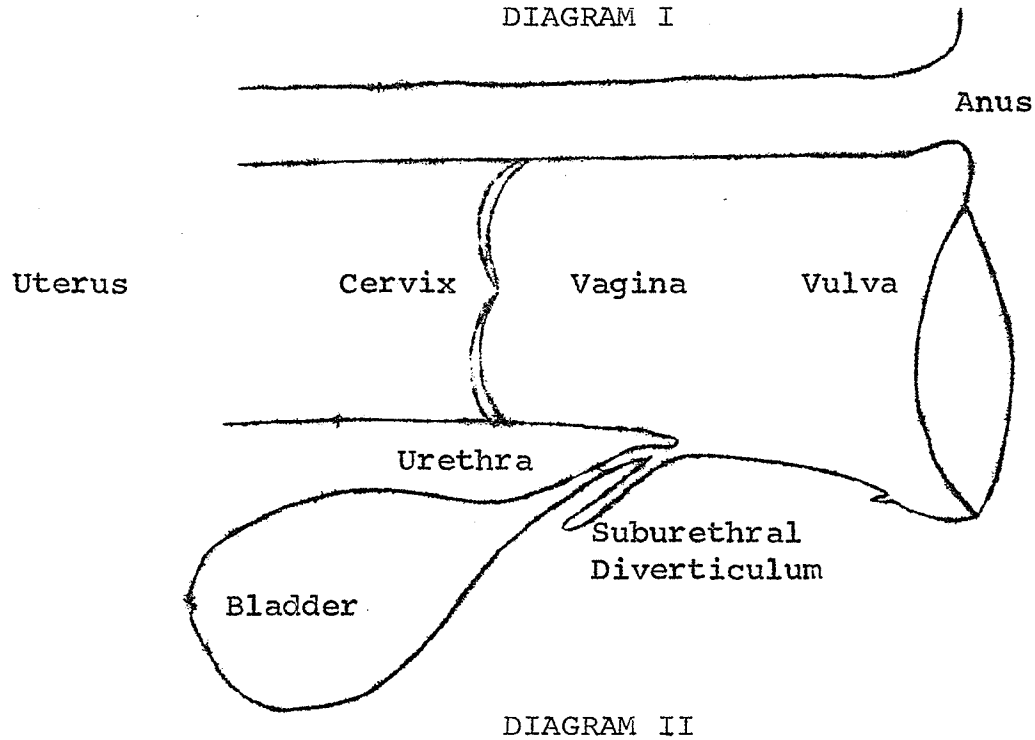
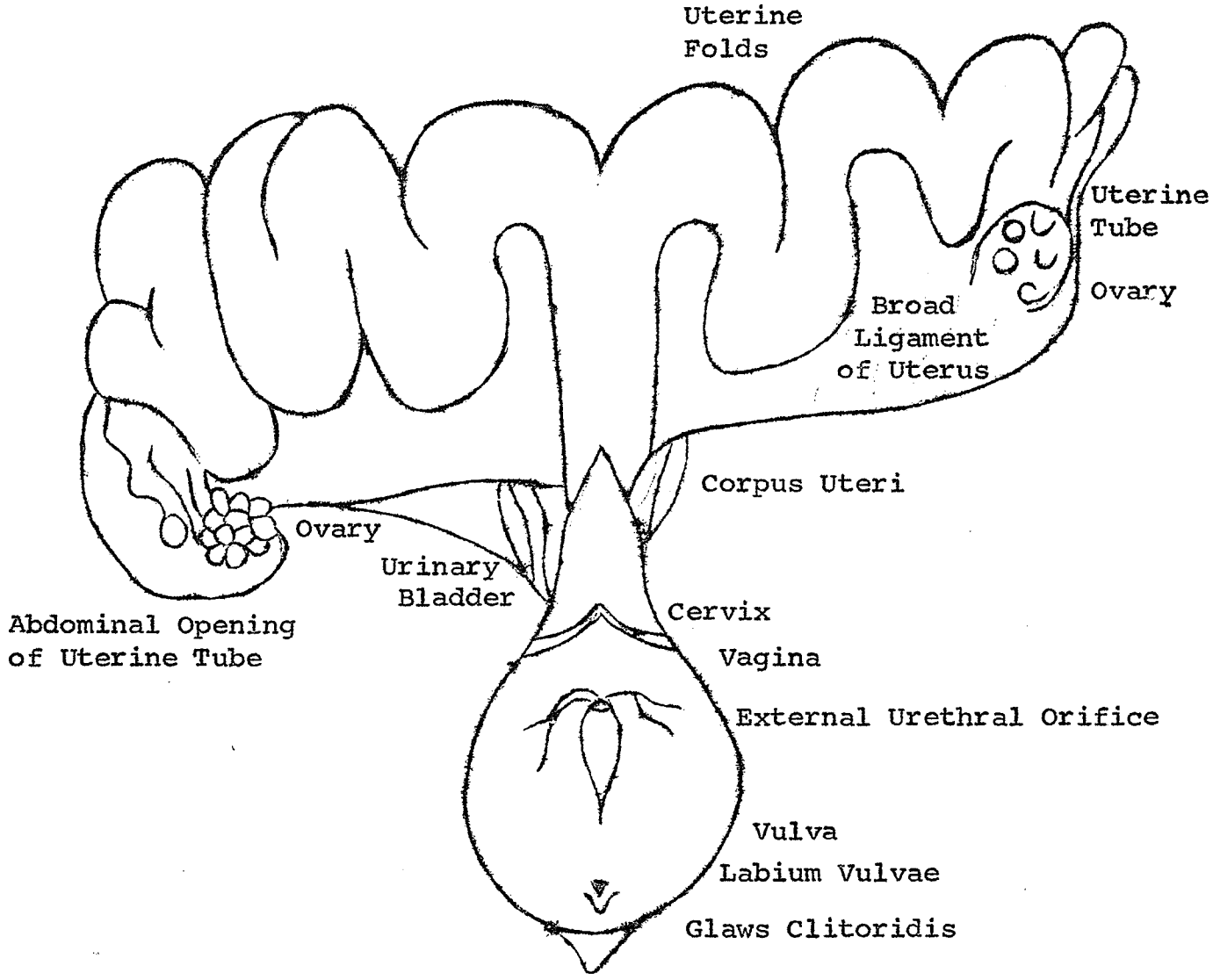


DIAGRAM II

SAGITTAL SECTION OF UROGENITAL TRACT OF SOW



DORSAL VIEW OF GENITAL ORGANS OF SOW