Sow Responses to Varying Feeding Planes of Sorghum Based Diets

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Raphael Githaiga Wahome, BVM, MSc. (Nbi)

A thesis submitted in fulfilment for the degree of Doctor of Philosophy in Animal Production in the Faculty of Veterinary Medicine, University of Nairobi.

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

Signed: ___________________________ Date: 21/9/1998
Dr Raphael G. Wahome.

This thesis has been submitted for examination with our approval as University supervisors.

Signed: ___________________________ Date: Sept. 21, 1998
Prof B.N. Mitaru,
Institute of Dryland Research,
Development and Utilization.

Signed: ___________________________ Date: 21-7-98
Prof P.N. Mbugua,
Department of Animal Production.
Dedication

During the long tiring time of work and waiting my family stuck with me. We suffered together. But they never complained. They encouraged me much. Much more, we prayed together. They all prayed. And God heard and answered their prayer. We are grateful to God through his son Jesus Christ for He kept us united.

That is why I dedicate this thesis to:

    Wairimu - my wife,
    Wahome - my son,
    Waithira - my daughter,
    Ndirangu - my son, he came when it was almost over.
    Thiong'o - my younger brother.
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Abstract.

Two studies were done to assess the influence of feeding levels of sorghum based diets on reproduction in primiparous sows. The first study was conducted to assess the effect of replacing maize with sorghum in pig diets in terms of digestibility of energy, protein, fibre. Four different iso-energetic and iso-nitrogenous diets were formulated to National Research Council (NRC) specifications and fed to eight finishing pigs (four barrows and four gilts) in a latin square designed experiment. The first diet (I) was a maize-soybean control diet. The second (II) was maize based, the third (III) was based on maize and sorghum in equal proportions by weight, while the fourth diet (IV) was based wholly on sorghum. Sunflower and cotton seed cake were the protein sources in diets II to IV. Dietary energy deficiencies were made up for by use of lard.

The digestibility coefficients of energy and protein for diets I to IV ranged from (77 to 82.3%) and (69.5 to 85.9%) respectively. There was a progressive improvement in energy and protein digestibility values with increase of maize in the diets.

In the second study, 24 gilts were fed low (L) and high (H) levels of experimental feed (14.2 MJ/kg DE; 14% CP) in gestation. The low group (L) was given 1 kg of feed per day while the high group was fed 2.1 kg per day. At farrowing gilts in each level were redistributed to a low (L) and a high (H) levels of lactation feed (14.6 MJ/kg DE; 15% CP) during lactation. The low group was fed 1 kg plus 0.3 kg per piglet in the litter daily and the high was fed 2.1 kg plus 0.5 kg per piglet. Combinations of feeding levels in gestation and lactation resulted in high-high (HH), high-low (HL), low-high (LH) and low-low (LL) levels. Gilt and piglet weights were recorded weekly. Seven blood samples were taken at 30 minute intervals weekly during lactation from 2 sows in each gestation-lactation feeding level subgroup, centrifuged and plasma taken for LH assays. Weaning was after a four week lactation when
daily feed allowance was reduced to 2 kg. The sows were slaughtered 28 days post-mating for reproductive system and carcass evaluation studies. Gilts on the high plane of feeding gained 30.3 kg while those on low plane gained 15.4 kg during gestation. The actual maternal body weight gain was 15.9 and 2.7 respectively (P < 0.05). Litter size, average piglet birth weight and conversion efficiency were unaffected by feeding level (P > 0.05). Over the lactation, the LL group lost 16kg, LH lost 17.1, HL lost 11.2 and HH lost 1.9 kg (P < 0.05). Litter and piglet weight gain was not affected by feeding level (P > 0.05) but feed efficiency was higher (P < 0.05) for the lower level of feeding.

High fed sows came back to oestrus eight days earlier than in the other three groups. Decreasing level of feeding was characterised by either prolonged anoestrus or conception failure. In the subsequent gestation, the gilts were slaughtered 28 days after mating. The four feeding levels had no carcass measurement differences at slaughter (P > 0.05). However, sows fed high in gestation released more ova, had heavier ovaries and placentas, higher foetal fluid volumes (P < 0.05) but did not differ from low fed sows in embryo weight (P > 0.05) by slaughter time. Similarly, sows fed high in lactation released more ova and had heavier placenta and embryos (P < 0.05). In contrast there was no difference in foetal fluid volume and ovary and corpora lutea weights with level of feeding during lactation. Increasing feed intake over gestation and lactation was associated with increased ovary, placenta and embryo sizes, and higher foetal fluid volumes (P < 0.5). However, the trend showed that these variations were more dependent on gestation rather than lactation level of feeding. The horn of uterus did not influence any embryo developments. Low fed gilts during gestation had lower plasma levels of luteinizing hormone during the first week of lactation but not thereafter.

It was therefore concluded that the level of feeding during gestation is important for embryo number and development in the subsequent reproductive cycle.
Chapter 1.

1. Introduction.

Livestock kept intensively (pigs, poultry, rabbits etc) depend on food glut or adequate storage of grain but this is a major constraint of grain production in most of the third world (Dinham and Hines, 1983). Probably the greatest constraint to pig keeping is the fact that pigs compete directly for the same feeds with humans. The nutritional requirements of pigs are remarkably similar to those of humans (Devendra and Fuller, 1979).

In Kenya, pigs are usually kept in enclosures and therefore must be fed. The quantity and quality of feed varies from region to region and from farm to farm. The pig industry in Kenya is characterised by farms having small number of sows of low productivity measured by the number of piglets weaned by the sow yearly. The low productivity may be due to any of the following reasons: (a) A short sow productive life especially where the sow is culled early due to poor productivity (Faust, Robison, and Tess, 1993). In monetary terms, it is more profitable to keep a sow for a long time as this results in higher returns and less replacement costs. (b) Poor sow nutrition (both undernutrition and malnutrition) during the gestation and lactation periods; (c) Poor housing that predisposes the sows to stress; (d) Poor quality boars or mating system; (e) Presence of subclinical reproductive disease leading to low litter size and high pre-weaning mortality.

In North America, where pig keeping is big business nearly all farms are dependent on home-grown grain. Only protein and vitamin-mineral premixes are brought to the farm. The feed companies selling the premixes usually assist in feed formulation and nearly always starter feed are bought. However, in Kenya, most farms do not have a sustainable feed base and so all sort of things are brought in resulting in great variability in feeding and in productivity.

The production unit of any pig production enterprise is the sow. She remains on the farm for an average of four years and during this time should be fed adequately to maintain her
productivity (English, Williams and Maclean, 1985). Most of the work done on sow feeding and reproduction has not been conclusive (Williams, Close and Cole, 1985). No work has been published in Kenya on the feeding of the sow and the effect of feeding on her reproduction. This study was therefore conducted; a) To assess the effect of variation of feed intake during gestation and lactation on growth and development of gilts and primiparous sows, and their litters. b) To assess the effect of variation of feeding level on levels of plasma luteinizing hormone during lactation and subsequent post weaning ovulation rates and embryo development.
Chapter 2.

Review of literature.

2.1 Numbers, distribution and productivity.

Pigs are found all over the world but are unevenly distributed with highest concentrations in the Far East, Europe, and North America (Aumaitre, 1987). The world's pig population is 839,852,000 (FAO, 1987). 39.1% of these pigs are in China, 17.9% in Eastern Europe and Russia and 10.4 and 7.7% in Western Europe and the U.S.A. (Aumaitre, 1987). Kensinger (1993) reported that the most widely consumed meat is pig meat with approximately 57 million tons marketed annually in Europe, North America, China and Japan and Russia and its neighbours. Production of pigs is increasing in most parts of the world but decreasing in the U.S.A. The highest increase has been in Western Europe but the increase rate has slowed down considerably due to feed shortage. Production and Consumption is increasing in China and Latin America and probably also in Africa. The numbers, distribution and productivity of pigs in Africa are not well documented and consist of mainly FAO estimates (FAO, 1987). In Kenya the population of pigs appear to have been increasing steadily in the last few years due to favourable market and feed situation but no actual data is available. In most of developing countries pigs form a minor livestock sector and contribute only 17% of the meat consumed (Aumaitre, 1987). Due to high feed costs, commercial production of pigs requires large numbers of sows in order to realize reasonable profit.

2.2 Productivity.

Productivity in pigs is measured in terms of pigs weaned or sold per sow per year. This number is dependent on litter size at birth and weaning, survival after weaning and the number of litters per sow per year. Survival from farrowing to weaning is greatly influenced by birth weight.

2.2.1 Litter size

Factors that influence litter size in pigs were reviewed by Clark and Leman (1986). Litter size was affected variously by
breed, current litter size, current interval from weaning to remating, nutrition over a long but indefinite period, disease and social environment. Litter size is an important parameter in pig production because it forms the base line on which actual products will arise. More specifically the number of piglets born alive is very important because they are the profit hope of the farm. These may vary with litter size, parity, farrowing duration, weight of the sow and sow's blood haemoglobin concentration (Zaleski and Hacker, 1993). A number of factors will contribute to small litters. Youth and age in sows, poor feeding and mating technique could all result in small litters (Robertson, 1975). Dewey, Martin, Friendship, Kennedy and Wilson (1995) regressed various parameters against litter size. Parity, lactation length and mating method all influenced litter size. Shorter or longer weaning to conception intervals had higher than average litter sizes. Current litter size was positively associated with future litter sizes and older gilts had higher litter sizes (Dewey et al., 1995). Xue, Dial, Marsh, Davies and Momont (1993) observed higher litter sizes in subsequent farrowings for longer lactations between 17 and 30 days and noted its biological constraint in preventing further shortening of lactation in the pig industry. The mechanism of this reduction, however, remained unexplained. These researchers backed previous suggestions (Edwards and Foxcroft, 1983a; Kirkwood, Lapwood, Smith, Moller and Garrick, 1984b) that shorter lactations may affect follicle maturation, ovulation process and embryo survival; all of which may lead to lower litter sizes.

Crossbred gilts had higher litter sizes than pure bred gilts. The higher litter sizes resulted from higher ovulation rates accompanied by higher embryo survival (Irgang, Scheid, Wentz and Favero, 1993). Ovulation rate was influenced to a greater extent by the breed of the gilts' dam which suggested a maternal breed effect which may however been confounded with growth rates. There were significant correlations between ovulation rates and number of live embryos (Irgang et al., 1993) and positive correlations between uterine lengths and ovulation rates (Davis, Robison and Toelle,
Gilts and sows fed chromium picolinate (a feed additive) in equal proportions with lysine had higher litter sizes (Lindemann, Wood, Harper, Kornegay and Anderson, 1995). Cao and Chavez (1995) demonstrated that copper deficient diets while not affecting litter weights, shortened parturition but caused smaller litter production and Walachi-Janiak, Raj St. and Fandrejewski (1986a) showed that feeding level did not affect litter size or any of the other products of conception composition.

2.2.2 Birth weight.

Birth weight of neonates in most species (including pigs) is important as it has bearing on neonate survival. Small neonatal lambs have a great disadvantage due to high surface area to weight ratio; poor vigour proceeding from poor ewe gestational nutrition; reduced energy reserves and proportionately smaller organs (liver, thymus, thyroid, spleen) which are unable to cope with stress (Alexander, 1974). This is the main reason that sheep lose 15-20% of their lambs. Sizes at birth are determined by many factors reviewed by Gruenwald (1974); Habicht, Lichtig, Yarbrough and Klein (1974) and Alexander (1974) some of which are early farrowing, maternal age, size and parity, number in the litter, sex of the foetus, genetic inadequacies, teratogenic agents, some foetal malformations, and specific diseases and non-specific conditions such as anaemia, or cardiovascular insufficiency. Maternal nutrition is also a very important cause of poor foetal growth probably due to its effect on placentation.

Placental weight has been shown to be a determinant of foetal growth. However, many factors affect placental weight, among which are exercise, nutrition and reduced uterine blood flow (Dwyer, Madgwick, Crook and Stickland, 1992). Placentas of low weight also have reduced exchange surface area which cause a limitation in nutrient absorption form the maternal circulation (Wotton, McFadyean and Cooper, 1977). Smaller and lighter piglets at farrowing had proportionately larger adrenal glands and higher levels of corticosteroid binding globulin though these differences
disappeared with age (Klemcke, Lunstra, Brown-Borg, Borg and Christenson, 1993). Their cells also had a greater response to ACTH. This effect is thought to be initiated while in-utero but it is not known exactly how this comes about though higher levels of corticosteroids (known to have growth inhibitory effect) may partially explain why lighter piglets at birth grow less fast than heavier ones.

2.2.3 Rebreeding of sows.

Lactational anoestrus is a well known characteristic of sows. However, most sows will normally come on heat within seven days of weaning (Kunavongkrit, Kindahl, Einarson and Edqvist, 1983). In any herd, a number of sows will fail to return to heat when they should. Nielson and Danielson (1983) discussed the problem of sows in poor body condition at weaning. Such sows are usually culled and when slaughtered their carcasses condemned by reason of emaciation. Nowadays most commercial herds are based on sows selected for leanness (required for high carcass grades at market) and higher milk production required for fast growth. If such sows are poorly fed or group fed, the disadvantaged sows get less feed and end up emaciated, especially during the lactation period.

Parity, breed, season, the housing system, the number of piglets weaned and reduction in body weight were all found to influence the length of the wean-to-oestrus interval (Vesseur, Kemp and Denhartog, 1994). In that study, sows fed in groups had higher incidence of prolonged wean-to-oestrus interval; but litter size at weaning and season both had an overriding effect over parity, feeding and weight loss. Sows weaning more than eight piglets had higher wean-to-oestrus interval and sows weaned in the hot season had longer intervals. However, artificial oestrus induction had an overriding effect on factors that prolonged the interval (Vesseur et al., 1994). Genetic variability for the wean-to-oestrus interval and had a low heritability of 0.17 (Tennapel, Devries, Buiting, Luiting, Merks and Brascamp, 1995a) though it tended to have an exponential distribution suggesting probable advantages in selecting against sows with prolonged intervals. Primiparous sows
that had an increased wean-to-oestrus interval had a high likelihood of repeat breeding as had primiparous sows with low plasma albumin (indicating poor nutrition) or high plasma gamma globulin (indicating subclinical infection) (Elbers, Vanrossem, Schukken, Martin, Venexsel, Friendship and Tielen, 1994).

Poor house conditions also increase maintenance requirements. The extra feed needed may not be offered or the sow may be incapable of physically consuming it. A drop of 15°C in environmental temperature may cause the maintenance requirements to rise by 60% (Nielson and Danielson, 1983). Prunier, Dourmad and Etienne (1993) fed a high and a low energy diet to primiparous sows during the lactation and showed a higher ovulation rate and a shorter wean-to-oestrus interval for the high fed sow. Delayed oestrus was associated with decreased oestradiol secretion by the ovaries the day following weaning. No associations were found between metabolic hormone levels and reproduction though plasma glucose levels were lower and free fatty acid levels higher for the high fed sows (Prunier et al., 1993).

Tennapel, Kemp, Luiting and Deveries (1995b) have proposed a model for studying the genetic variation of the wean to oestrus interval in the sow. The interval between start of cyclicity and oestrus, and the length of the oestrus cycle were removed from the model because of low variability. There being no evidence in literature of genetic variability in incidence of silent oestrus, it was also removed from the model. It was concluded that the main cause of genetic variability in sows is due to the fickleness of the period from weaning to the start of cyclic activity. Tennapel et al. (1995b) also suggested that variability was due to the ability of the sows to respond to such appropriate external stimuli as boar contact. Severe loss in body weight, seasonal effects and other forms of stress are known to suppress this ability. However, this ability does not render itself open to selection. Selection for reproduction limits feed intake capacity, reduces body reserves at first parturition, increase age at first parturition, and increase milk production capacity. All these effects may cause
severe body weight losses during the lactation and therefore prolong the subsequent wean-to-oestrus interval.

2.3 Feeding of sows.

2.3.1 Common pig feedstuffs.

Soybeans are the commonest type of protein and supply all the amino acids. Soybean meal is used as a standard for evaluation of protein feeds (Krider, 1982). Cotton seed meal has 50% feeding value of Soybeans because it is lower in protein and energy and higher in fibre. It is also lower in the essential amino acid lysine while sunflower seed meal has an even lower quality than cotton seed meal. Sunflower has been fed to various age groups of pigs but has poorer feed conversion, lower digestibility and lower intake than other protein sources (Ochetim and Attia, 1979; Wahlstrom, Libal and Thaler, 1985). Sunflower seed meal has low protein availability due to its high crude fibre content. Breakdown of protein that takes place in the colon and caecum is of little benefit to the pig as the resultant amino acids are not absorbed (Jorgensen, Sauer and Thacker, 1984). After absorption, nitrogen excretion in urine is higher for sunflower diets (lower biological value) than for soybean diets due to lower lysine levels. Therefore diets having sunflower seed meal as the source of protein can be improved by addition of synthetic crystalline lysine (Wahlstrom, Borg and Libal, 1986; Zatari and Sell, 1989). More than half of the amino acids in feeds are contributed by cereals which form more than 70% of most rations. This contribution of cereals to animal amino acid requirements diminish the effect of sunflower cakes' lower protein quality (Thacker, Sauer and Jorgensen, 1984). Maize, sorghum, barley, oats, wheat and rye, in that order of preference may be used as the main feed base in combination with the above protein sources (Krider, 1982). Maize and grain sorghum are used extensively in livestock feeds. The utility of maize as feed in swine production is renown and sorghum is the backbone of the pig industry in the south-western USA (Cohen and Tankaley, 1976). Sorghum and maize are recorded as having similar nutrient levels and can therefore be used inter-changeably but neither is
adequate as the sole source of protein due to insufficiency of several essential amino acids (Eckert and Allee, 1974). Cousins (1979) showed 5% lower protein and 4% lower energy digestibility coefficients in sorghum based diets but similar amino acid profiles in sorghum and maize. Lysine, methionine and tryptophan are the first limiting amino acids in maize while lysine and threonine are the first and second in sorghum (Eckert and Allee, 1974; Brudevold and Southern, 1994). Methionine in sorghums may be limiting but tryptophan is not (Ward and Southern, 1995; Brudevold and Southern, 1994). Brudevold and Southern (1994) cautioned on addition of synthetic methionine in sorghum based pig starter diets stating fears of tissue damage. Sorghum based diets have a lower performance in comparison to the maize based ones. There are such intrinsic differences between sorghum and maize as lower levels of metabolizable energy, linoleic acid, potassium and zinc, tocopherol, folacin, vitamin B6, arginine, histidine, lysine and threonine (Hansen, Knabe and Borgoon, 1993). After studies on essential amino acids in sorghum, Hansen et al. (1993b) suggested histidine as the probable cause of the lower performance in sorghum based diets. The starch-protein matrix in grain sorghum is harder and more resistant to penetration by moisture, hence the lower digestibility (Chen, Huber, Simas, Theurer, Yu, Chan, Santos, Wu, Swingle and Depeters, 1995). The matrix can be loosened by heat, mechanical pressure or moisture. Lin, Knabe and Tanksley (1987), however, reported similar dry matter and energy digestibility coefficients in maize and sorghum, but lower nitrogen retention and amino acid digestibility for sorghum. Higher protein diets are usually more efficient than low protein ones but lower protein diets that supply all the essential amino acids may be give adequate performance and be cheaper. Wahlstrom et al., (1986) fed growing pigs diets varying in protein for 12 to 28% and observed similar performances where the essential amino acids were adequately supplied. Similarities between sorghum and maize even extend to dairy cattle where cows fed steam flaked sorghum based diet had similar intakes and milk yield but higher butterfat and
lower milk protein levels than those fed maize based diets (Oliveira, Huber, Simas, Theurer and Swingle, 1995).

2.3.2 Feeding of sows: general information.

The sow's plane of feeding determines the weight gain in gestation and loss of weight in lactation as well as the subsequent breeding performance. Sows on higher fat diets and lower fibre diets lose less weight in lactation and have shorter wean-to-oestrus intervals in warm season. However, high fat / low fibre diets had little advantage over low fat / high fibre diet in daily litter weight gain (Cheng and Yen, 1994). The nature of the feed offered also has an effect on conversion of the feed and therefore sow performance. Feed particle size in lactation diets influences sow and litter performance. Sows fed diets ranging in particle size from 400 μm to 1200 μm by Wondra, Hancock, Kennedy, Hines and Behmke (1995) had similar back-fat loss, wean-oestrus interval and body weights but different percentage of sows returning to oestrus. An 11% difference in litter weight gain was observed between sows on lowest and highest particle size diets. Litter survival was not affected by dietary particle size. However, increased incidence of oesophageal and gastric ulceration were noted for the lower particle size diets.

Feed eaten by the sow during gestation is utilized for maintenance, growth, and deposition into the products of conception. Energy and protein requirements can vary widely with physiological stage, reproductive performance, behaviour and housing conditions (Dourmad, Etienne, Prunier and Noblet, 1994a). Therefore, calculations of requirements for sows should consider these variables. Energy requirements during lactation are greatly influenced by milk production but housing and behaviour are more important during gestation; hence the need to adapt rations to each physiologic period (Dourmad, Etienne and Noblet, 1994b). Amino acid requirements are low in gestation but high in lactation. Falaschini, Volpelli and Trombetta (1994) fed different levels of protein and supplemental amino acids and showed that sows fed low protein diets (11% CP) but supplemented with adequate amounts of
lysine, methionine-cystine threonine and tryptophan performed as well as those on high protein diets but had lower protein catabolism as indicated by milk urea values. However, sows fed 5% protein diet catabolized protein in the last third of gestation and mobilized more body tissue and had higher piglet mortality over the subsequent lactation than those fed 14% protein (Shields, Mahan and Maxson, 1985). The amount of feed energy deposited into the products of conception is dependent on litter size and time (Beyer, Jentsch, Hoffman and Schiemann, 1994a). The energy inputs also increase with parity causing heavier litters as well as greater energy costs due to the accompanying foetal membranes and fluids. Parity and energy intake in gestation determine the energy input to the mammary glands and the effect of lactation accentuates it during lactation. Live weight losses of gestating or lactating sows were connected with mobilization of body fat and protein. Greater body weight losses were associated with increased proportions of body fat to body protein (Beyer et al., 1994a). Energy requirements for maintenance increased from 435 to 473 kJ ME/kg liveweight per day with increased parity during gestation. The last month of any gestation had an increase of 6% in heat production (Beyer, Jentsch, Hoffman and Schiemann, 1994b). Schams, Kraetzi, Brem and Graf (1994) concluded that secretory patterns of metabolic hormones (especially insulin-like growth factor-1 (IGF-1)) may indicate a mechanism for prevention of protein mobilization during lactation.

2.4 Feeding sows in gestation and lactation.

2.4.1 Sow energy requirements.

The recommended dietary levels for sows by the National Research Council (NRC) (1988) is the same for both lactation and gestation; that is, 3340 Kcal/Kg of diet. This ensures that a sow on a dairy ration of 2 kg of feed gets 6400 Kcal/day during gestation and more over and above that during lactation depending on the litter size (based on the rule of the thumb that for each piglet the sow gets an extra 0.5 kg of feed). Only a few sows having more than 6 piglets have been able to eat this much. The
aims of good feeding are to achieve higher average piglet birth weight, higher piglet survival, higher weaning weights and shorten the weaning to oestrus interval (Coffey, Diggs, Handlin, Knabe, Maxwell, Noland, Prince and Gromwell, 1994), but in a large cooperative study involving 999 litters, diet or feeding level was only shown to influence weaning to oestrus interval.

Study of the sows' energy requirements is complicated by several factors reviewed by O'Grady (1985). When the gilts are first mated they have different energy reserves and different energy reserves similarly at the end of their breeding life. In addition the effect of energy requirement varies with the environment, size and breed of the sow (O'Grady, Elsely, MacPherson and McDonald, 1975; Hovell, MacPherson, Crofts and Smart, 1977). Voluntary feed intake is also variable depending on the ambient temperature, sow weight change, litter weight change, feeding systems, energy concentration in the food, nature of feed and previous intake (O'Grady and Lynch, 1978). Higher ambient temperatures affect appetite and have been shown to influence foetal and piglet growth, mobilization of body reserves and return to oestrus after weaning. Shorter light periods have also been associated with shorter weaning to oestrus interval and lower plasma FSH concentration (Prunier, Dourmad and Etienne, 1994). Dove and Haydon (1994) reported that increasing nutrient concentration decreased feed intakes but increased nutrient intake and piglet average daily gain. Cooler season were associated with higher intakes and better piglet gains (Dove and Haydon, 1994). Diets higher in dietary fat and higher protein content (14 vs 16%) were shown to delay return to oestrus in both primiparous and second parity sows but only fat content had an effect on second parity sows (Weeden, Nelssen, Thaler, Fitzner and Goodband, 1994). Dietary calcium levels do not influence sow reproduction. However, slightly higher than normal levels improve milk calcium levels and average daily gain (Miller, Hartsock, Erez, Douglas and Alstonmills, 1994).

2.4.2 Energy Requirements in Gestation.

Energy requirements in sows during gestation were summarized
by Verstegen, Verhagen, and Den Hartog (1986). Feed is required for optimal development of the sow and the products of her conception. The amount fed should be sufficient to facilitate gilt or sow growth without causing excessive fatness. The weight of the sow is an important parameter influencing the maintenance requirements. Weight gain is also important for the longevity of the sow and while it is affected markedly by feeding level it has minimal effects on in-utero foetal development (Verstegen et al., 1986). Energy feed variation during pregnancy does not affect litter size (Adams and Shearer, 1975; Reese, Moser, Peo, Lewis, Zimmerman, Kinder and Stroup, 1982a; Verstegen et al., 1986; Walach-Janiak et al., 1986a). Heap and Lodge (1967) reported weight gains of 35.9 kg during gestation and showed that protein part of the gain is located in the abdominal muscle, the reproductive organs and mammary tissue and the fat gain in the back of the dam. Over a long term study of four parities, Elsely, McPherson and Lodge (1968) reported no variation of body composition among various levels of dietary treatments at the end. However, body fat in that trial was used as a source of energy for growth of more essential tissue, maintenance and reproduction. Body composition did not influence reproduction but extremely thin back fat layer led to inabilities of regaining weight after weaning regardless of feeding plane, a feature referred to as thin-sow syndrome. The pre-trial body fat in gilts was estimated between 20-30 kg (Elsely et al., 1968). Whittemore, Franklin and Pearce (1980) related decreased body fat content in fresh gilts to persistent selection for lean and concluded that body fat should be the prime characteristic to consider in determining sow feed allowance. The gilts in that experiment gained 2.3 kg in form of subcutaneous fat and lost 6.9 kg of the same. Therefore, it is difficult to make targets or recommendations for all sows and sow fatness monitoring is necessary to feed sows properly (Whittemore et al., 1980). With the expectation of 10 piglets at farrowing, litter weight of 15 kg and an additional weight of 5 kg in placenta and foetal fluids is anticipated. It is also expected that the sow
will gain 25 kg in weight half of which will be lost in lactation. Therefore, feeding should be such that the sow does not have to mobilize body reserves during gestation to support foetal growth and also high enough to support its own weight gain (Verstegen et al., 1986). Feeding should also take into account the environmental temperature, humidity and sow activity (Prunier et al., 1994). The efficiency in conversion of energy from feed to gain and products of conception is still uncertain (Verstegen et al., 1986). However, high level of feeding in gestation results in too much body weight gain which is followed by high body weight loss and lower feed intake during the lactation. Thus an inverse relationship between the voluntary feed intake during the gestation and lactation has been suggested (Lodge and Hardy, 1968; Brooks and Smith, 1980; Cole, 1982; Williams, Close and Cole, 1985; Yang, Eastham, Philips and Whittemore, 1989; Dourmad et al., 1994). Hovell et al. (1977) calculated the sows energy requirements during gestation to be 23.65 MJ/kg (N x 6.25) gain and 39.56 MJ/kg fat gain. None of the low diets have gone much lower than the NRC (1988) recommendations and the expected effect on the sow due to the lower than recommended is obscure. However, the decision of the level of energy to feed sows during the gestation depends on the desired weight gain; which may be anywhere between 10 and 40 kg (O'Grady, 1985). The effect of the energy level is implicated in delaying the subsequent return to oestrus and the decision not to return to heat may be made by 'the sow' as early as the first week of lactation (Foxcroft, Shaw, Hunter, Booth, and Lancaster, 1987).

2.4.3 Energy requirement during lactation.

Sow energy requirement during lactation varies with all factors mentioned above. Sows that have been on high plane of feeding during gestation have been reported to refuse feed (Aherne and Kirkwood, 1985; Weldon, Lewis, Louis, Kovar, Giessemann and Miller, 1994). This refusal results in wasting. Baidoo, Aherne, Kirkwood and Foxcroft (1992a) reported losses of 16.3 kg and 39.2 kg for high fed sows and low fed sows in lactation. The sows also lost 2.1 and 6.6 mm in back-fat thickness respectively and had
9.5ng/ml and 7.6ng/l LH post-weaning. Losses similar to these were recorded by Weldon et al. (1994) who also showed higher insulin levels for standard fed sows than for those fed ad-libitum and so associated greater weight loss in lactation to higher insulin levels. It has long been noted that sows which lose large amounts of weight during lactation exhibit prolonged weaning to oestrus period. It has also been reported that energy intake during lactation is inversely related to sow weight loss (Elsely et al., 1968; O'Grady et al., 1975). Reese et al. (1982a) demonstrated that energy variation influences the sow's return to oestrus after weaning. This is especially so for the primiparous sow. The relationship between intakes during gestation and lactation and their combined or separate influence on the sow's return to oestrus is not well established. However, Reese et al., (1982b) described the effects of level of feeding in one lactation on the subsequent gestation and lactation. Varley and Prime (1993) did not find any differences among four feeding levels on conception rates but noted a slight increase in the interval from weaning to onset of oestrus with decreasing level of feeding. Similarly these authors reported that low fed sows were found to have lower back-fat thickness at the end of lactation and were slow in regaining the back-fat even to remating and though their feeding levels affected the body weight gain, it did not affect either plasma levels of progesterone or prolificacy. Varying contents of specific amino acids in iso-nitrogenous diets did not influence daily intake in primiparous sows (Trottier and Easter, 1995). In that trial the sows receiving lower ratio of tryptophan to branched chain amino acids (BCAA) had slightly lower intakes in the second week of lactation but the hybrid sows lost significantly less weight during four weeks of lactation while the yorkshire-duroc sows performed similar to the controls. There were no litter performance differences in the trial (Trotttier and Easter, 1995). Baidoo (1989) reported a ten days difference in the wean to oestrus interval between high and low fed second parity sows; a higher non-significant embryo survival was also noted.
2.5 The reproductive system

2.5.1 The ovary: Structure and function.

The ovary in the pig is located at the end of the oviducts just beneath the seventh lumbar vertebra and within the ovarian bursa which is an extension of the mesosalpinx. It is a cylindrical organ with a distinct hilus (the centre is large and distinct) and a smooth surface which often contain prominences that give it an irregular or lobulated appearance. These projections are follicles or large corpora lutea whose diameter measures 0.7-0.8cm and 1.2-1.5cm respectively (Sisson and Grossman, 1904). The surface of the ovary is covered with a squamous epithelium similar to the peritoneum and continuous to the mesovarium. This epithelium is underlaid with fibrous connective tissue called the tunica albuginea ovarii. The outer layer usually called the cortex (zone parenchymatosa), is made of a mixture of granulose cells, primordial oocysts and fibrocytic interstitial cells normally called the theca cells. The primordial oocysts are large cells having an eccentric nucleus surrounded by cuboidal granulose cells. These are preformed in all female piglets at farrowing. The interstitial cells are highly adaptive and pleomorphic and convert to macrophages, secretory epithelia around the follicle and back to fibroblasts after ovulation. The inner layer is often called the medulla (zona vasculosa) and is formed by large blood vessels lymphatics, nerves and connective tissue with elastic and reticular fibres and the rete ovarii (residual developmental tissues).

The ovary goes through cyclic changes as follows: follicular development whereby a large number of follicles are at different stages of development, ovulation, corpora lutea formation (with about 10 to 15 corpora lutea resulting from each ovulation (Chen and Dziuk, 1993), degeneration of follicles, and degeneration of the corpora lutea (Banks, 1974).

Follicular development involves selection of the primordial oocyst and ploriferation of the granulosa cells (zona granulosa) around into several layers. Then it is called a secondary oocyst. The proliferation continues and these cells become highly secretory
forming fluid around most of the oocyst. A layer of granulosa cells is left intact around the oocyst (cumulus oophorus) and is separated from the oocyst by a thick glassy fibrous tissue (zona pellucida). The fluid around the oocyst is the liquor folliculi and the space is the follicular antrum. The fluid accumulates in the antrum until the oocyst is ejected after the rupture of the cyst (ovulation). Follicular growth and maturation is of interest as it forms an integral and important step in reproduction in the female. Follicular maturation is not the same as oocyst maturation (Thibault, 1977). It involves selection, growth and ovulation while oocyst maturation is characterised by continued cumulus cell division, oocyst resumption of meiosis, cytoplasmic maturation and maturation of the oocyst membrane. These steps are necessary to make a fertilizable ovum (Thibault, 1977). Thereafter, the remaining void is filled up with blood and again there is rapid proliferation of the granulosa cells. The void is also highly vascularized. It is now called corpus haemorrhagica. The theca-interstitial cells around the granulosa cells change to lipogenetic cells. This is the corpus luteum. The corpus luteum bulges over the surface of the ovary. If the ovum is fertilized, it continues in existence until just before farrowing. Otherwise it regresses after about 12-15 days and the cycle begins all over again (Charlesworth, Grady and Schwartz, 1983).

2.5.2 The ovary: endocrinology.

Traditionally the ovary has been allocated the role of a passive but receptive partner in the female reproduction with the major and decisive role being played by the pituitary gland under direction of the hypothalamic part of the brain. However recent information show that rather than just react to instructions, the ovary is in control of reproduction and the hypothalamus, the pituitary, the uterus (together with other reproductive organs) responding to its prompting (Adashi, 1994). The ovary is a hub of biological activity and various sections have differing duties and products.

The most important products of the ovary are the steroid
hormones. The steroids are pregnenolone, progesterone, 17α-hydroxy-progesterone, dehydroepiandrosterone, androstenedione, testosterone, oestrone, and 17β-oestradiol (Adashi, 1994). The ovarian cells responsible for the production of each of the above hormones have been identified. The follicular cells (mainly granulosa cells) are responsible for the production of oestrone and oestradiol, though they are capable of producing progesterone. Theca interstitial cells have been shown to be the precursors of androgens. To manufacture oestrogens, the granulosa cells must receive a supply of androgens (mostly androstenedione) from the theca interstitial cells. The androgens are converted to oestrone and further aromatized by the activity of 17β-hydroxy steroid dehydrogenase to oestradiol by loss of c19 and elimination of 1β and 2β hydrogens of the precursors A ring (Bjersing, 1967). The corpus luteum is formed by the residual follicular granulosa cells after ejection of the ovum and is responsible for the production of pregnenolone, progesterone and 17α-hydroxyprogesterone (Fowler, Fox, Edwards, Walters, and Steptoe, 1978). Thus granulosa cells are capable of production of both oestrogens and progestins. The precursor of the steroidogenesis is cholesterol normally from the circulating serum lipoproteins. The protein part cleaves at the cell membrane and the cholesterol is either transported to the mitochondria for steroidogenesis or stored in esteric form in the cytoplasm. Since vascularization is required to meet the demand of cholesterol for steroidogenesis, the follicle being less vascularized produces little progestins while large amounts are produced by the same cells following massive vascularization after ovulation. Pregnenolone is formed first in the mitochondria and converted rapidly in the cytoplasm to through dehydrogenation and isomerization to 17α-hydroxyprogesterone (Sulimovici and Boyd, 1969).

The androgens (c19) are produced by the theca-interstitial cells. All steroid synthesis starts with progestin (c21; i.e. pregnenolone and progesterone) synthesis. This means that the theca-interstitial cells are endowed with capability not only to
absorb cholesterol from circulation and convert these to progestins but also to convert them to dehydroepiandrosterone and androstenedione. These cells have abundance of 17a-hydroxylase and 17-20 desmolase enzymes necessary for the first steps of aromatization (Sasano, Okamoto, Mason, Simpson, Mendelson, Sasano and Silverberg, 1989). Haney and Schonberg (1981) raised granulosa and theca-interstitial on separate plates as either pure or co-cultures and at three different stages of follicular development. The isolated granulosa cells produced more progesterone and less oestradiol than when co-cultured. However, production of oestradiol by the isolated granulosa cells increased dramatically and superseded that of progesterone in the presence LH and androgens (Tsang, Ainsworth, Downey and Marcus, 1985). The bigger follicles produced more oestradiol and this synthesis varied with the concentration of androgens in the media and increased with the size of the follicle while progesterone synthesis declined. Porcine theca-interstitial cells are also capable of aromatization and indeed produce as much oestradiol as the granulosa cells but this synthesis remained fairly constant amid varying androgen concentrations (Foxcroft and Hunter, 1985; Haney and Schoniberg, 1981; Tsang et al. 1985).

Stress has been shown to modify ovarian endocrine function as higher than normal levels of glucocorticoids lead to poor follicular development and anovulation (Viveiros, 1991). When sows were treated with adrenocorticotrophic hormone (ACTH), the follicles were found to contain higher levels of cortisol but lower concentration of oestradiol, testosterone and androstenedione. Addition of androstenedione to such follicles caused increased oestradiol concentration indicating that cortisol inhibited androgen synthesis. There were no gross ovarian morphological changes but the ovaries had more follicles containing fewer viable granulosa cells and there was a higher proportion of atretic follicles (Viveiros, 1991).

A number of protein are also made in the ovary. Most of these are enzymes responsible for the above activities. Others have
important reproductive regulatory activities. Inhibin occurs in two forms and is under serious scientific investigation. However, it has been attributed the role of gonadotrophin release regulation as well as suppression of ovarian androgen biosynthesis by reducing receptivity of the theca-interstitial cells to gonadotrophins (Burger and Finlay, 1989). Another protein labelled activin has been shown to enhance reception of luteinizing hormone (LH) by granulosa cells (Ying, Becker, Swanson, Tan, Ling, Esch and Ueno, 1987). Follistatin is another protein distinct from the above two that depresses follicle stimulation hormone (FSH) release (Ying et al., 1987). The potential advantage of that activity is not yet clear. A substance of indeterminate biochemical nature named Gonadotrophin surge-inhibiting factor (GnSTF) which has short term selective inhibitory effects on secretion of FSH by the pituitary has been identified. The follicular antral steroids have a key role in follicle growth and in the regulation of their own synthesis (Babalola and Shapiro, 1988) but the type and nature of this control is not well understood. All steroid synthesis increased during oestrus but with exception of 20α-dihydroprogesterone declined shortly before ovulation. Generally the contents of the follicular fluid seem to have contradictory effects on follicular cells. At one time they stimulate maturation of granulosa cells, enhance oestrogen and progesterone secretion, increase receptor sites for LH and FSH and at other times inhibit effects of prostaglandin F 2-α, reduce LH and FSH receptor sites and reduce adenylcyclase activity. It appears that the effect that these contents will have are dependent upon the status of the cell and Foxcroft and Hunter (1985) have proposed experiments on many sows at each known phase of follicular development to determine the exact nature of ovarian control on its activity.

2.5.3 Gonadotrophins: source and function.

Gonadotrophins are tropic hormones secreted from the pituitary gland and have an effect on the gonads. The pituitary gland, otherwise called the hypophysis, is located in a deep bowl like fossa in the middle of the cranial cavity within fascia tissue
called sella turcica (Sisson and Grossman, 1904). The hypophysis has dual embryological origins; with a pharyngeal extrusion upwards and a diencephalon intrusion distally. The parts of pharyngeal origin form the adenohypophysis (anterior pituitary and the nerve part forms the neurohypophysis (posterior pituitary). The adenohypophysis secretes the gonadotrophins, adrenocorticotropin, somatotropin and thyroid stimulating hormone. The neurohypophysis secretes the antidiuretic hormone (ADH) and oxytocin. The gonadotrophins are follicle stimulating hormones (FSH) and luteinizing hormone (LH) produced by the basic staining cells (basophils), and prolactin produced by the acid staining cells (acidophils). Prolactin is a light protein molecule whose molecular weight is estimated at 25,000. FSH has an estimated molecular weight of 29,000 and LH of 45,000.

Among the known functions of FSH and LH are the development of the theca-interstitial cells of the ovary; formation of the follicular antrum which forms a store of follicular hormones by enabling secretion of fluid by the granulosa cells; control and regulation of follicular growth and development (Ireland, 1987). Follicles exist in ovary under a state of rest awaiting recruitment and selection. Recruitment means starting off the resting follicles on the growth journey while selection is deciding those to atret and those to ovulate (Adashi, 1994). The follicles most likely to be selected are larger, have higher mitotic index in their granulosa cells and higher concentrations of FSH and oestradiol in their follicular fluid. Such follicles are said to be dominant over the others. Thus they inhibit development of other follicles (DiZerega et. al., 1983). As follicles develop, the primary oocyst previously inhibited by granulosa cells must also resume its maturation, a process that requires priming by LH (Thibault, 1977) while 17α-20β-hydroxyprogesterone is required for the second meiotic division of the oocyst. There is controversy on the role of gonadotrophins on follicular selection in the sow. Ireland (1987) states that gonadotrophins determine which follicles will be recruited to form the next crop of ova. This is not certain as, in
pigs, follicular steroid synthesis is intra-regulatory in presence of FSH, which causes a decrease in progesterone synthesis, and accumulation but an increase in oestradiol synthesis. FSH, androstenedione and testosterone separately lack this ability (Evans, Lischinsky, Daniel and Armstrong, 1983). Lacker, Beers, Meuli and Atkin (1987) even postulated a mathematical model which determines which follicle will be selected by the 14-16 day of oestrus. The model is based on the concentration of FSH, LH and oestradiol, the degree of follicle maturity and density of their receptors on the follicular cells. Foxcroft and Hunter (1985), on the other hand, think that follicles are always growing in the sow except when suppressed by pregnancy or by other follicles. These grow to a diameter of 6-7mm and become dominant follicles which are ripe for recruitment by FSH. Not all these follicles will ovulate as developing follicles can be come atretic at any time. Some may ovulate immature oocysts. The ovulation of increased numbers of completely mature oocyst as well as advance preparation of many LH sensitive follicles for maturation in vitro needs a better understanding of follicular cycles (Thibault, 1977). Follicular development in the luteal phase or during lactation is not necessarily arbitrary as it prepares for sufficient ovulation rates. Even as late as day 14-16, the number of follicles larger than 6 mm in diameter are below the observed ovulation rates; giving a strong suggestion of continued recruitment in the follicular phase (Foxcroft and Hunter, 1985; Britt, Armstrong, Cox and Esbenshade, 1985). Theca interstitial cells always have receptors for LH but granulosa cells have receptors for FSH and develop receptors for LH under the influence of FSH in the presence of oestradiol (Rani, Salhanick and Armstrong 1981). These receptor must be maintained by the presence of FSH. That is why the pre-ovulatory surge of LH is so effective in causing ovulation in late weaned sows and not so effective in extremely early or zero weaned sow (Buck and Schoniberg, 1987).

FSH and LH after reception at the receptor site activate the second messenger cAMP which mediates the necessary effects of the
first messenger (Adashi, 1994; Foxcroft and Hunter, 1985). The theca-interstitial cells enhance production of progestins from cholesterol and desmolation/hydroxylation to form androgens (androstenedione) under the effect of LH while the granulosa cells increase cellular growth and differentiation including formation of LH receptors under the influence of FSH which also induces aromatization of androstenedione to oestriol. Even from day zero of the lactation, a number of follicles larger than 5 mm are noticeable though the majority are small sized. But there is continuous increase in follicular size of the smaller ones during lactation (Britt et al., 1985) while the bigger ones degenerate and become atretic. The gonadotrophin levels during lactation are low due to suppression of FSH secretion by inhibin and probably some other ovarian non-steroidal factors and suppression of LH by the effect of suckling mediated through reduced hypothalamic production of gonadotrophic releasing hormone (GnRH). Britt et al. (1985) observed that injection of GnRH, weaning, improved nutrition, boar exposure and split weaning during lactation increased LH secretion and follicular development. The exact role of the gonadotrophins during lactation is not determined but their levels do increase after the first three weeks of lactation which may indicate readiness to resume cyclicity. Prolactin has been shown to play no role in regulation of LH release and whereas injection with oestradiol in late lactation cause an LH surge, it is unable to do so early in lactation (Britt et al., 1985). Immediately after weaning, LH episodic pulses increase and though FSH levels increase, the pattern is neither clear nor explained (Britt et al., 1985; Foxcroft and Hunter, 1985).

2.5.4 The oviducts.

These are two long tubes which are fimbriated at the ends. The length varies from 15 - 30 cm. The fimbriated end has a large opening into the abdomen. Embryos and ova in the oviducts appear quite able to survive without any elaborate media support until the blastocyst stage by which time the embryo are in-utero. Thus the main function of the oviducts is to convey ova and spermatozoa
towards each other as well as convey fertilized ova to the uterus (Youngs, Ford, McGinnis and Anderson, 1993).

2.5.5 The Uterus.

The uterus is composed of a short body and two long and flexuous horns. The horns are freely movable and are connected to the broad ligament which continues to link with the bladder lateral ligament. The body of the uterus is about 5 cm. Its end does not project into the vagina but appears to be continuous with the cervix. The internal mucosa has rounded prominences which dovetail to occlude the cervical canal. The length of the uterus was found to be related to litter size. Chen and Dziuk (1993) demonstrated that restricting space allowance for the developing foetus resulted in increased early embryonic mortality. Embryonic survival was greatest (87%) for embryos allocated more than 50 cm of uterine space and lowest (33%) for those allocated 5 cm. However, there were no differences in foetal weight for those that survived to day 35. But these effects would only be observed where there were sufficient ovulations to cause overcrowding and this differences would exist only up to day 17 and again between day 29 and 35 of mating (Chen and Dziuk, 1993). Male foetuses allocated more than 25 cm space were heavier after day 40 than their female counterparts but those allocated less than 25 cm were lighter. A tendency of greater survival for females was noted where uterine space was restricted. Irgang, Scheid, Wentz and Favero (1993) had results at variance with those above. These authors reported higher ovulation rates for cross bred gilts than in pure bred gilts, no differences in embryo survival and shorter (but not significant) uterine lengths for cross bred gilts.

2.5.6 Ovulation and Fertilization.

Prolificacy in pigs is measured by the number of piglets born in each litter. This differs significantly among breeds. Chinese breeds are famous for their prolificacy while crossbred sows have larger litters than their corresponding purebred parents (White and Wheeler, 1995). A number of components are responsible for litter size; follicular development (Biggs, Tilton, Craigon,
Foxcroft, Ashworth and Hunter, 1993), ovulation rates (Hunter, Biggs and Faillace, 1993); ovulation time (Faillace, Biggs and Hunter, 1994); embryonic survival (Bazer, Thatcher, Martinat-Botte and Terqui, 1988; Youngs et al., 1994) and foetal survival (White, McLaren, Dziuk and Wheeler, 1993). It is generally accepted that the more prolific sows have better follicular development, higher ovulation rate, shorter ovulation time and better embryonic and foetal survival. However, Christenson (1993) noted equal ovulation rates in Meishan and Large white/Landrace crosses. Ovulation rates for the Meishan increased at a somewhat faster rate with age and parity but individual embryo had less allantoic fluid, lighter embryo and placentas. The reason or indeed the effect of the lower allantoic volumes and lighter embryo and placentas is not known (Christenson, 1993). The increase in ovulation rates with age plateaus quickly after the age of 8 months in the large white breed. Therefore this increase would not be noted in slower maturing gilts. The breed embryonic survival variability is variably observed with Galvin, Day, Haley and Wilmut (1993) and Ashworth, Haley and Wilmut (1990) reporting a higher survival at 20th day and at 30th day of gestation, respectively. Bazer et al. (1988) and Terqui, Bazer and Marinat-Botte (1990) observed no differences but Christenson (1993) observed lower embryonic survival.

2.5.7 Early embryonic development.

After ovulation the ova stays in the oviducts for up to three days. It appears that levels of oestradiol must wane while progesterone levels rise to allow sufficient dilatation of the oviduct isthmus for the embryo to pass (Pope et al., 1990). Assuming that the sow/gilt has been mated around the ovulation time, the ova are fertilized within about four hours. Fertilization in pigs is always higher than 95%. Fertilization is followed by rapid mitotic cell division and eventually form a tight cluster of cells within the zona pellucida called the morula. Four to five days after ovulation a void, called blastocoele starts forming in the morula thus signalling the start of the blastula stage. The
The embryo is now called a blastocyst.

Both before and after blastulation, the embryo migrate randomly throughout the uterus by both peristaltic and antiperistaltic uterine contractions. The migration is minimal for the first 6 days but peaks between the seventh and ninth day. By day 12 the embryos occupy both horns although proportionately more stay in the horn of origin. Oestrogens secreted by the embryo are required for the migration as inanimate objects do not migrate. The embryos may repel one another as they are eventually placed equidistance from one another. For pregnancy to continue, the body of the uterus, as well as both horns must be occupied by some embryos. In fact, the proportion of the uterus occupied is directly proportional to the probability that the pregnancy survives. If 50% of uterus is unoccupied 100% of pregnancies fail, 75% occupancy leads to 70-80% failed pregnancies while 87.125% is associated with 40-50% failed pregnancies (Dziuk, 1985).

A signal must be exchanged on day 12 (before day 13 and after day 11 of onset of oestrus) between the dam and the embryos for the pregnancy to continue as removal of all the embryos in one uterine horn does not stop the pregnancy. Once this signal is exchanged, pregnancy continues even if all the embryos are removed (a state of pseudo pregnancy). The signal is contributed collectively by the embryos. Four embryos are the minimum required to make an adequate signal. However, a minimum of five corpora lutea are necessary to sustain pregnancy. Because oestrogens have been demonstrated to sustain pregnancy when given prior to day 14 and because of positive correlations between plasma levels of oestrone sulphate and the number of embryos between day 20 and 28, oestrogens are assumed to be the signal between the dam and the embryos. Therefore both space (20cm per embryo) and oestrogens produced by embryos are needed for normal embryo development (Dziuk, 1985).

Meanwhile, both the uterus and the blastocyst secrete a host of proteins (between day nine and eighteen) some of which have been characterised. This proteins are assumed important for maternal recognition of pregnancy and implantation and are of four types.
These types are, the mitogens (insulin like growth factor I and epidermal luminal fluid mitogen), binding and transport proteins (uteroferrin and retinol binding proteins), Protease inhibitors and trophoblastic specific proteins (Simmen and Simmen, 1990). The secretion of this proteins, which are important for the initial embryo development, is sustained for as long as the embryos secrete oestrogens. It is suggested that secretion of endometrial prostaglandins is reoriented into the uterine lumen rather than into the vasculature by these secretions (Geissart, Zavy, Moffat, Blair and Yelin, 1990). Placental oestrogens also decrease the arterial tone of the arteries supplying each unit. This localised vasodilation allows elevated flow to foetal-placenta unit even with reduced total uterine blood flow (Ford and Stice, 1985).

About the eighth day the blastocyst starts to elongate forming long sheet like tissues many times its original size. The central part forms a mass of cells destined to differentiate to the various body organs. The embryo then starts to enfold around its longitudinal axis. The cells that extend beyond the inner cell mass after folding are not required by the embryo for organogenesis. These form the start of the foetal membranes and implantation (Patten, 1948). The membranes formed are the yolk sac which in pre-implantation period functions as tool for absorption of sustenance form the lumen of the uterus. This is the part of fore gut not included in the embryo when it en folds. The amnion forms as the embryo folds (at around 15-20 somites) and the two lunar like tips grow around the embryo and encompass it. The formation of the amnion is complete by the time the embryo is 6mm long. The cavity in between the amniotic membranes becomes filled with fluid which functions as shock absorber against physical injury of the embryo. The allantois starts as a diverticulum from the part of hind gut left out when the embryo folds. Its distal end becomes dilated enormously but the proximal part narrows to form a cylindrical stalk together with the proximal parts of the yolk sac and amnion (Patten, 1948). The dilated part expands to a semilunar sac which extends further to eventually completely go round the embryo;
elongated along the longitudinal axis of the uterus. It becomes highly vascularized. Its peripheral parts fuse with the serosa (formed from the trophoblast or trophoectoderm) to form the chorion. The newly fused membrane is in intimate contact with the uterine mucosa whatever the folds. The two are highly vascularized and form the porcine epitheliochorial placenta (Patten, 1948). The functions of the yolk sac are taken over by this structure and it becomes vestigial.

2.5.8 Functions of the foetal membranes.

The foetal membranes form the placenta and also function as fluid sacs. The allantois contains fluid which acts as the first barrier to external shock. Knight, Bazer, Thatcher, Franke and Wallace (1977) observed that the allantois fluid volume increase in pigs rapidly between day 20 and 30 of gestation and the decrease thereafter until day 40 when there is another rapid rise until day 80. Henceforth the fluid volume decrease until parturition. Around day 30 the allantois fluid volume for each foetus is about 100 ml. There are very few studies concerning allantois fluid volume, its regulation and its effect on the outcome of pregnancy.

The amniotic sac carries the fluid whose basic function is to buffer the foetus from external shock or pressure. It also functions as a reservoir for lung fluid and a depot for urine. The foetus swallows the amniotic fluid in breathing and excess fluid is either exhaled or removed in the urine. There are no accurate methods of measuring the amniotic fluid in-utero (Fisk et al., 1990). In humans, the previously used paracentesis has become unethical and its place has been taken over by ultrasonography whose reliability is far from confirmed. Thus most experiments are carried out perinatally on the membranes that have not ruptured (Fisk, Tammirandon, Nicolin, Talbert and Rodeck, 1990). However, Baron, Morgan and Garite (1995) state that less than normal amniotic volume (oligohydramnios) is associated with foetal distress, smaller birth weights and baby weakness after delivery. Oligohydramnios is also implicated as a cause of pulmonary hypoplasia by increasing uterine compression of the foetus. In an
experiment to test this statement Kizilcan, Tanyel, Cakar, Buyukpamukc and Hicsnomez (1995) showed that lung to body weight ratios were lower in rabbit litters that had less amniotic volume than controls. The experimental litters' lung airways were found to be histologically immature. Polyhydramnios (higher than normal amniotic volume) is reported to cause premature and prolonged labour, maternal discomfort, uterine irritability and premature rupture of foetal membranes leading to foetal distress (Fisk, et al., 1990). The foetus plays a part in regulation of the fluid by intestinal absorption and urination. Experiments by Trimmer, Leveno, Peters and Kelly (1990) that involved injection of distilled water and saline in the amniotic sacs showed that the foetus swallowed the fluid and had increased urination but more than 70% of the saline ended up in the maternal circulation. The fluid is absorbed through the placenta to form part of maternal body fluids so as to maintain normal amniotic volume and pressure (Brace, 1989). The pathogenesis of amniotic fluid disorders is poorly understood. There have been few animal studies. But oligohydramnios may be caused by non-labour uterine contractions which occur in greater frequency in the latter half of gestation which cause reduced thoracic dimensions and reduced foetal oxygenation (Scheerboom and Tavarine, 1985). Harding, Hooper and Dickinson (1990) reported that lamb foetal lungs are expanded by breathing in utero and that this breathing is not impaired by oligohydramnios though it resulted in reduced lung volume because of raised lung airways pressure. Increased spinal flexion in goat and ewe foeti was also seen to cause reduced amniotic volume (Scheerboom and Tavarine, 1985).

Lodge, Friend and Wolynetz (1979) carried out a proportionate study of the products of conception at 56 and 112 day of gestation. At 56 day of gestation the empty uterus weight, fetuses, placenta, and uterine fluid were 2.6, 1.7, 2 and 3.5 kg, while at day 112 they were 4.6, 10.4, 2.1, 2.1.

2.5.9 Embryonic survival.

Mortality of the foetus may occur at any time but the first
ten days (preimplantation) are critical firstly, and the next ten days (implantation) secondarily; the crucial period being between hatching from the zona pellucida to implantation (somewhere between day eight and day twelve of ovulation) (Cassar, King and King, 1994). After fertilization and the initial cell multiplication stage, embryo survival determines prolificacy. There are a variety of theories as to causes of losses of some of the embryos. Individual gilts with higher rates of gain in early gestation have elevated embryo mortality (Varley and Prime, 1993). The gain rates are associated with feed level (Dyck and Starin, 1983). The more advanced embryos synthesize oestradiol earlier which advances the uterine environment to support their own survival to the detriment of the less advanced embryos (Morgan, Geissert, Zavy, Shawley and Fazleabas, 1987). The embryo are at various stages of development because of a prolonged ovulation period (Xie, Broermann, Nephew, Geissert and Pope, 1990). The result is that embryo form earlier ovulations advance earlier, synthesize oestradiol earlier, advance uterine secretions and therefore survive better than the less advanced embryos which are more sensitive to uterine environment changes. The embryo sex effect, however, is contradictory. Male embryo were found to develop faster than the female ones in the first ten days of ovulation but at farrowing or even at day thirty of gestation there were no differences in sex ratios (Cassar et al., 1995).

The chinese breeds renown for their prolificacy, produce three to four piglets per litter more than European breeds (Haley and Lee, 1993). The higher prolificacy is not necessarily from higher ovulation rates. Most gilts and sow release 17 - 22 ova in each cycle (Hunter and Picton, 1995). The difference is primarily due to higher survival of the embryo. Sows having shorter intervals between the onset of oestrus and ovulation tend to have lower embryonic survival. Hunter and Picton (1995) shortened duration of the period between onset of oestrus and ovulation in Meishan pigs to that of European breeds by hCG administration. No significant differences between controls and treated pigs were observed in
ovulation rates, uterine weight or uterine length but controls had more live embryos and higher survival rates at the 30th day of gestation. The embryo of both groups had similar crown to rump length and allantoic fluid volume but the controls had heavier embryos and lighter and shorter placentas. Hunter and Picton (1995) therefore concluded that hCG administration would not be beneficial to gilts or sows as it does not increase ovulation rates but causes earlier ovulation (Lambert, Williams, Lynch, Hanharan, McGeady, Austin, Boland and Roche, 1991) which was detrimental to embryo survival. Earlier ovulation results in prolonged ovulation with some embryos' development being poorly coordinated with the uterine biochemical environment (Pope, 1988; Pope, Wilde and Xie, 1990). The differences in ovulation times is a result of different follicular development and oocyte maturation mentioned above. However, while ovulation in Meishan pigs has been shown to occur over a shorter duration than that of the European breed (Terqui et al., 1990), heterogeneity of ova in European breeds has not been demonstrated (Biggs et al., 1993).

2.6 Nutrition and Reproduction.

The nutrition and reproduction of interaction has been well documented in many species. Frisch (1982) reported that women that have better nutrition have shorter inter-birth intervals. However, suckling frequency and period confounded the nutritional effect. Some women will not cycle when nursing (Bongart, 1980). Those that do are found to be enjoying reasonable nutritional status. Work done on gorillas indicate that poorly fed gorilla mothers have a greater frequency of nursing and that this frequency is associated with longer inter-birth intervals (Stewart, 1988). LH, FSH and testosterone levels have been shown to increase with diet improvement in rams and the increases are much higher in the hot season (Walkden-Brown, Restall, Norton, Scaranuzi and Martin, 1994).

Well fed sows are associated with large litters (Wilkins and Martinez, 1983). Responses to nutrients are equivocal (Williams, Close and Cole, 1985). Several studies on the effect of feeding
level on reproduction (Baidoo et al., 1992a; Baidoo, Kythagoe, Kirkwood, Aherne and Foxcroft, 1992b; Kirkwood, Baidoo, Aherne and Sather, 1987; Aherne and Kirkwood, 1985) show that low feeding plane is associated with less weight at parturition and weaning, higher body fat loss, lower preweaning survival and lower than normal LH levels in subsequent gestation. One of these reports state that levels of LH remain low in lactation but increase dramatically towards the end of lactation. Nutrition level in gilts around breeding age affects ovulation positively but embryo survival negatively. However, there is dearth of information and lack of evidence that low lactation feeding level influences subsequent ovulation rates and embryo survival (Kirkwood, Thacker, Korchinski and Laaveld, 1990).

Many workers have carried out studies that involved slaughter of the sow at the end of the experiment; the aim of those experiments being to demonstrate how feed or feeding affects the sows body proportions or composition. Lodge et al. (1979) gave pregnant and non-pregnant sows similar feed allowances and then carried out serial slaughter to determine how pregnancy affected sow body proportions and feed efficiency. Pregnancy gain was as efficient as that of normal growth and carcass, viscera, liver and blood proportions of the body were similar in both groups throughout the gestation. The empty uterus weight of the pregnant sows was four and five times as heavy as that of non-pregnant sows at 56 and 112 day of gestation respectively. This study was followed up by another two by De Wilde (1980a; 1980b). The first study had the objective of determining protein retention by pregnant gilts and the latter study was to determine the energy retention. Pregnant gilts retained more protein but most of it in the products of conception. When the gilts were feed restricted to an extent of losing 10 kg of live weight only 1 kg of this was protein. The non-pregnant gilts were marginally superior in energy efficiency and retained about 10% more energy (De Wilde, 1980b). However, this conclusions may be speculative because of the low retention of energy in the carcass (Maternal body) in comparison to
retention in the products of conception. Later composition studies calculated conversion efficiency for the products of conception 6.5g DP/g; 79.2KJ ME/g and maternal body gain (3.66g DP/g; 48.4 KJ/g) (Walach-Janiak et al., 1986a). Protein deposition decreased linearly with increase in feed intake per day at the very low intake gilts gained protein and lost fat. Pregnant gilts gained more weight and deposited more water than empty gilts and at the higher feeding levels their maternal body weight gain was higher. Fat deposition was not influenced by pregnancy but maintenance requirements were slightly higher (444 KJ ME/kg$^{0.75}$ versus 424 KJ ME/kg$^{0.75}$) for the pregnant gilts. However, they were more efficient in protein deposition (65.4 KJ ME/g v 104.3 KJ ME/g) (Walach-Janiak et al., 1986b). High fed sows deposited more fat and protein during gestation than low fed sows though there were no differences between gestating and virgin pigs in the maternal body gain and there was a decrease in efficiency of fat deposition from 14 to 5% with increased intake. Piglets born from the various dietary treatments had similar body composition (Hovell et al., 1977). Thus pregnancy does not support increased feed efficiency and the apparent advantage in protein retention by gestating pigs is short lived and disappears by the end of the first week of lactation (Hovell et al., 1977).

2.7 Body fat and reproduction

A number of workers have hypothesised that a minimum proportion of body fat to the live weight is necessary for reproduction processes to continue. Menarche in women reportedly fails in women with low body fat either due to starvation or exercise (Frisch, 1982). Studies of fertility in women as affected by nutrition have been reviewed by Prentice, Poppit, Goldberg and Prentice (1995). Most of these studies are retrospective as famines caused by war, drought, severe winter freezes and other harvest blights are not usually anticipated by the researchers or the physiological bodies they worked on. Most studies show fecundity at the harvest time in Sahelian Africa to be higher than at other times and this places the nutritionally demanding third trimester
in the hungry season. Women have the highest proportion of body fat (20 to 30% depending on the state of nutrition) among the following species; rodents (<10%), goat (8%), cow (14%), sheep (8%), pig (18%) and baboon (3%) (Prentice et al., 1995). Women lost half their body weight during gestation and delivered successfully. However, they have one of the longest gestation period of any species per unit body size making their daily maintenance and pregnancy requirement low. Finally, women having less body fat (because of less food availability in the Gambia) were 15 times less basal metabolic rate and the prediction of the pregnancy requirement was best done by the pre conception body fatness (Prentice et al., 1995). Johnstone et al. (1989) showed a linear relationship between body fat in sows at weaning and interval from weaning to oestrus. The relationship was explained as due to a negative energy balance experience in lactation than that immediately post weaning which resulted in energy deficit. Gravid gilts and sows gain more weight in form of protein, fat and moisture. This gain is mainly due to the products of conception and there is no evidence of pregnancy anabolism. The higher moisture contents was due to foetal fluids and liveweight changes in gestation and lactation were mainly in form of water and fat (Shields and Mahan, 1983). There have been changes in sow genetic make up in the last 40 years. Sows are now selected for increased lean and the modern sow has little tendency to fatness (Yang et al., 1989) making gilts commence on their reproductive life with minimal fat reserves. The situation is further complicated by the fact that weight gain can occur concurrently with fat loss. Development of the products of conception is given a higher priority than development of maternal body and if the dietary supply may adequately support maternal body gain then protein deposition is given priority provided that diet is not low in protein (Everts and Dekker, 1995a). To make fat these new genes require more feed. This is a major challenge as the lactating sow has a high propensity for fat catabolism even in an adequate feed situation. Nevertheless for optimal breeding capability, sows must
have more than 10 mm back-fat thickness at position two (P2) (65 mm lateral of mid back line around the position of the last rib). Sows should be farrowed with back-fat thickness of more than 18 mm and be weaned with at least 12 mm (Yang et al., 1988).

Body fat accounted for only 25% of the variation in the interval from weaning to oestrus (Johnson, Fogwell, Weldon, Ames, Ullrey and Miller, 1989) and was not the sole determinant of the delay thus negating its use in prediction of oestrus.

2.8 Feed energy and reproductive hormones.

Differing reports on the effect of energy on reproductive hormone secretion have been reported. However, it is generally agreed that nutrition affects ovarian activity by altering the rates of gonadotrophin release into the blood stream (Hafez, 1959; Allen and Lamming, 1961). Hafez (1959) suggested that this is a protective syndrome against further stress. In low fed heifers, LH levels increased over 3 oestrus cycles; firstly during the peaks followed by basal levels. Progesterone levels were higher in the first oestrus but decreased progressively over the next two oestrus cycles leading to the hypothesis that ovarian hypo-function was not due to LH hyposecretion but to reduced sensitivity of the ovarian tissue to LH (Gombe and Hansel, 1973). A repeat of the experiment by Apgar, Aspros, Hixon, Scatman and Hansel (1975) showed depressed LH levels as well as corpora lutea of reduced size which produced lower amounts of progesterone in-vitro compared to those of normally fed heifers. The depressed progesterone levels were probably due to reduced substrate levels for the low fed heifers since the secretion did not differ in-vivo.

As stated above thin wasted sows usually fail to return to heat after weaning. It is difficult to tell which of the sows especially primiparous sows come back to heat after weaning because about 22% of the primiparous sows come back to heat after a prolonged period of 20-80 days while some do not come back to heat at all (Love, 1979). Low fed sows had lower LH concentration than high fed sows and the sows that failed completely to come back to
heat post weaning had even lower LH concentration (Kirkwood et al., 1987).

Lactational anoestrus is due to prolactin secretion as a result of suckling stimulus (Palmer, Teague and Venzke, 1965; Stevenson, Cox and Britt, 1981). Palmer et al., (1965) reported a reciprocal relationship between prolactin and the gonadotrophins, which resulted in suppressed follicular development in the sow. But more recent work has shown that while LH secretion is suppressed during lactation, FSH is not (Stevenson et al., 1981). These results raised suggestion that prolactin may also suppress ovarian activity during lactation.

Shaw and Foxcroft (1985) described a significant rise in plasma LH levels soon after weaning as well as an inverse relationship with the weaning to oestrus interval. The peak FSH concentration after weaning was significantly correlated to the ovulation rate but not to the weaning to oestrus interval. Therefore lack of ovarian activity in lactation was attributed to lack of LH stimulation (Edwards and Foxcroft, 1983b).

Foxcroft et al., (1987) concluded that LH secretion during lactation may be used in predicting return to oestrus in terms of which sow and at what time. FSH secretion was found to be too variable during both lactation and immediately post-weaning to be of much use in prediction of oestrus. No functional relationship between FSH and the length of the period between weaning and remating has been reported. The effect of the inverse relationship between FSH and prolactin on ovarian activity around weaning has not been demonstrated in spite of the number and variety of reports on FSH, LH and prolactin. Neither is prediction of which sow will delay or fail to return to oestrus.

2.9. Carcass characteristics.

Comparative slaughter of pigs has been used to study the fate of feed intake over long periods (growth, gestation, lactation, or even parities) (Everts and Decker, 1994a; 1994b; Rozeboom, Pettigrew, Moser, Cornelius and Kandelgy, 1994). It is understood that manipulation of reproductive performance of sows would be more
effective with understanding of the influence of nutrients on various body components. Many workers have reported the proportional and compositional variation of sows or sows tissues after comparative slaughter (Elsely, Anderson, McDonald, McPherson, and Smart, 1966; 1968; Hovell et al., 1977; de Wilde, 1980a; 1980b; Everts and Dekker, 1994a; 1994b; 1994c; 1995a; 1995b) among others. All these studies show fat accretion during gestation and mobilization during lactation to varying degrees. Protein accretion has been reported to vary with parity and protein level in the diet (Shields et al., 1985).

Ovary (paired) weights in gilts averaged between 3.6 - 17.4 grams while kidney weights averaged 350 to 383 g (Andres, Green, Clapnyper, Cline, Dickman, and Thomford, 1993; Wu and Dziuk, 1995). Ovulation rates varied between 12.5 - 18.5; embryo survival, 65 - 92.1; uterine weight at 30 days, 1.12 - 1.17 Kg; embryo weight, 1.2 - 1.4g; placenta weight, 17.2 - 23.1; and allantoic fluid volume, 144 -149ml (Hunter and Picton, 1995; White and Wheeler, 1995; Wu and Dziuk, 1995). The tenth rib fat thickness was 2.5 to 3.2 cm while percentage lean was between 52.9 and 56 (Andres et al. 1993). Some total measurements taken by Shield and Mahan (1983) at end of gestation were as follows; Head and forelegs 8.6-9.5kg, Cleaned out visceral organs 4.4-5.4kg, Intestinal content 5.4-12.9kg, uterus 1.2-19.5kg, mammary tissue 3.0-7.6kg, uterine fluid 0.85-16.8 kg.

Carcass characteristics are best assessed by the method refined by Fahey (1977). This method used various measurements made on carcasses to estimate the percentage lean tissue of the whole carcass. The best measurement was that of the loin eye area at the last rib after cutting the carcass transversely and perpendicularly to the vertebral column and placing a grid on the cut surface of the longismus muscle to estimate the area. Other measurements that could be used were perpendicular to the skin back-fat measurements on the first or last rib and 45 mm form the midline. Regression equations were proposed that could be used to estimate the carcass percentage lean. This method may be acceptable
if only carcass assessment was required. When dealing with sows, total amount of body fat and its fluctuations are of more importance. Carcass measurements are terminal and can be obtained only once. With the advent of ultrasonography, live measurements of back-fat thickness are obtainable and these could be used to calculate total body fat (King, Speirs and Eckerman, 1986). In sow nutritional experiments, there is need to estimate the changes in animal composition and especially the fat component. King et al. (1986) showed relationships between live weight, back-fat thickness and carcass fat. These writers also reported high correlations between body water and fat to the indices of body composition. Linear back-fat thickness was found to be the best indicator of body fat as a proportion of live weight. The equation shown below was used to derive body fat:

\[
\text{Carcass fat/Live weight} = 0.095 + 0.00858 \text{ back-fat (40mm form midline at tenth rib).}
\]

The relationship would be very useful in estimation of body condition and its effect on reproduction. On the same sow, different back-fat thickness reflect different physical and chemical composition (Whittemore and Yang, 1989). The differences come about as a result of the original fat reserve at commencement of measurement and feeding level in lactation as well as litter size. The amount of body fat at parturition influenced the subsequent wean to oestrus interval length. As feeding during gestation and lactation and litter size influences Rebreeding studies should be done on how this factors influence body fat. Absolute levels and possible changes and causes of these changes of body fat are required and this should be obtained without having to slaughter the sows (Whittemore and Yang, 1989). The body fat in sows fluctuates a lot in the reproductive cycle but unlike cattle protein mobilization is minimized. Whittemore and Yang (1989) reported a gain in protein as the sow actually lost weight (in form of fat). The carcass measurements in sows need to be
approached in energetic terms of energy gained or lost from the sow and how much of this can be accounted for in terms of piglet gain and there determine the efficiency of utilization of feed. A recent report by Everts and Dekker (1995b) did not set the issue to rest but proposed long term equations (i.e. over several parities) and gave a more complete chemical analysis of most tissues of the sow’s body and thus emphasised the importance of having accurate measurements of boy fat in live sows.
Chapter 3

Nutritional evaluation of maize and sorghum based diets.

3.1. Introduction

Maize-soybean diets have been commonly used in feeding of pigs. However, there is need to use other feedstuffs, such as sorghum where it is available, as an energy source. Maize and sorghum have similar nutrient levels but sorghum has lower energy and protein digestibility and lower protein biological value probably due to its tannin content. Neither maize or sorghum is adequate by itself as an animal feed. Cotton seed cake and sunflower seed cake are more easily available as protein sources than soybean cake in Kenya. Cotton seed cake is lower in protein and energy and higher in fibre content than soybean. The quality of sunflower seed cake protein is poorer than that of cotton seed cake. The lower protein quality in cotton seed cake and sunflower seed cake is offset by the fact that the bulk of amino acids come from cereals in most diets. Available pig feeding standards are mostly derived from studies elsewhere based on maize-soybean as reference diets. To use these standards effectively, information on the comparative feeding value of sorghum-cotton seed/sunflower seed cakes diets to that of maize-soybean diets for sows was useful, especially in the subsequent feeding trial studying the effects of level of feeding on sow performance.

The objective of this experiment was therefore to compare the feeding value of the maize and sorghum based pig diets in terms of digestibility coefficients.

3.2. Materials and methods.

3.2.1. Feed preparation.

Four iso-energetic (14.2 MJ/kg) and iso-nitrogenous (14% CP) diets were prepared as follows:
1) Diet I was a maize-soybean diet (control).
2) Diet II was based on maize but soybean was replaced with a mixture of cotton seed and sunflower seed cakes.
3) Diet III had maize and sorghum in equal proportions and protein was supplied as in diet 2.
4) Diet IV was based on sorghum and protein supplied as in diet II.

Lard was used to make up the energy level of each diet to meet the NRC requirements (National Research Council, 1988) (Table 1). Chromic oxide was included at 0.25% as an inert marker.

3.2.2. Experimental design.

Eight pigs (4 barrows and 4 gilts) were used in a 4 by 4 latin square design blocked by sex. The experimental pigs were kept in 8 crates measuring 120cm long, 48cm wide and 80cm tall. The front of the crates had a feed trough measuring 45 cm wide, and 24 cm deep. Water was supplied to the pigs through watering nipples attached to the crates. The animals were kept on a test diet for 7 days (1 period) followed by a rest period of 4 days. The animals were meal fed individually twice a day on amounts predetermined at approximately 4% their live weights. Faecal samples were collected directly from the rectum by initiation of the defecation reflex twice every day (10 AM and 4.00 PM) on day 6 and 7 of each test period. These were dried in the ovens set at 60°C. The 4 samples obtained from each animal in each period were pooled and ground together after which routine proximate analysis and gross energy determination were done (A.O.A.C., 1975). Similar analyses were performed on 2 samples of each of the four diets. Chromic oxide concentration in each sample (bulked faeces and feed) was determined using the modified technique of Fenton and Fenton (1979) and colour read at 440nm. Digestibility coefficients were calculated using the following equation. Apparent digestibility coefficient % =100-(100x(% indicator in feed/ % indicator in faeces)x % nutrient in faeces/% nutrient in feed.

3.2.3 Statistical analyses.

The effect of sex was assessed using one way ANOVA. However, sex did not influence digestibility coefficients and so was not
Table 1. Composition of diets used in experiment 1.

<table>
<thead>
<tr>
<th>Ingredient (%)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum</td>
<td>-</td>
<td>-</td>
<td>36.8</td>
<td>73</td>
</tr>
<tr>
<td>Maize</td>
<td>80.4</td>
<td>74.1</td>
<td>36.8</td>
<td>-</td>
</tr>
<tr>
<td>Lard</td>
<td>0.1</td>
<td>1.9</td>
<td>2.4</td>
<td>3</td>
</tr>
<tr>
<td>Bone meal</td>
<td>1.75</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Cotton seed cake</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Sunflower seed cake</td>
<td>-</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>16</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Limestone</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Salt</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Premix</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Cost (Ksh/kg)</td>
<td>5.02</td>
<td>3.77</td>
<td>3.4</td>
<td>3.06</td>
</tr>
</tbody>
</table>

Analyzed chemical composition of the diets.

<table>
<thead>
<tr>
<th>Analyzed composition (%)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (%)</td>
<td>91.5</td>
<td>92.3</td>
<td>92.3</td>
<td>91.4</td>
</tr>
<tr>
<td>GE (MJ/Kg)</td>
<td>17.7</td>
<td>17.8</td>
<td>18.4</td>
<td>18.3</td>
</tr>
<tr>
<td>Crude Protein (%)</td>
<td>13.2</td>
<td>13.8</td>
<td>12.5</td>
<td>15.3</td>
</tr>
<tr>
<td>Crude Fibre (%)</td>
<td>4.2</td>
<td>7.4</td>
<td>7.1</td>
<td>7.5</td>
</tr>
<tr>
<td>Crude Fat (%)</td>
<td>6.6</td>
<td>7.0</td>
<td>8.1</td>
<td>8.1</td>
</tr>
</tbody>
</table>

Digestibility values of the diets

<table>
<thead>
<tr>
<th>Digestibility (%)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDM (%)</td>
<td>86.9</td>
<td>85.5</td>
<td>85.2</td>
<td>85.5</td>
</tr>
<tr>
<td>DE (MJ/Kg)</td>
<td>13.4</td>
<td>14.3</td>
<td>15.1</td>
<td>14.3</td>
</tr>
<tr>
<td>DCP (%)</td>
<td>11.3</td>
<td>10.5</td>
<td>9.2</td>
<td>10.7</td>
</tr>
<tr>
<td>DCF (%)</td>
<td>2.5</td>
<td>3.1</td>
<td>3.1</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Calculated sorghum contribution to total tannins in the diets (Jacobs et al., 1997).

| Tannins g/kg | 0 | 0 | 8.3 | 16.4 |

Notes:  
DDM - Digestible dry matter.  
DE - Digestible Energy  
DCP - Digestible crude protein  
DCF - Digestible crude fibre
included in the final statistical latin square model. The digestibility coefficients were subjected to Latin square ANOVA using the program Statview™ (BrainPower, Inc, 1986) on the Apple Macintosh Computer. The means of significant effects were separated by Scheffes’ F-test (BrainPower, Inc., 1986).

3.3. Results and Discussion.

3.3.1. Chemical composition of diets.

The four diets were formulated to have similar chemical composition and in particular to be iso-energetic and iso-nitrogenous as shown in Table 1. Laboratory analysis results of the diets are also shown in Table 1. The dry matter, energy, crude protein, crude fibre and crude fat proportion of the diets varied from those calculated at formulation but were acceptable. The variation was due in part from the fact that analysis of ingredients was not done and the possibility that the ingredients lacked uniformity. Considerable variation was observed in contents of sorghum and oil cake samples (Jacob, 1993) even when these were from the same source.

Even after addition of lard crude fat level ranged between 6.6 and 8.1%. Diets with increased content of lard were of higher gross energy (GE) content. Lard was included increasingly from diet I to IV. This meant that diets with more sorghum had higher levels of lard and therefore higher GE. Digestible energy (DE) varied from 13.4 to 15.1 MJ/Kg. The diets with higher proportions of lard had higher digestible energy (DE). However, diet III (based on maize and sorghum in equal proportions) had highest level of DE.
The observed CP contents for the diets were 13.2%, 13.8%, 12.5% and 15.3%. Diet IV and III had the highest and the lowest levels of CP respectively. However, diet I had the highest level of digestible crude protein (DCP), followed by diets IV and II. The lowest levels of DCP were observed in diet III.

The crude fibre contents for diets I to IV were 4.2%, 7.4%, 7.1% and 7.6% respectively. These fibre ranges were within the acceptable ranges. The digestible crude fibres ranged between 2.5 and 3.1% the higher levels being for diets II and III.

3.3.2. Digestibility coefficients.

The digestibility coefficients and the summary of mean squares of the latin square ANOVA for the digestibility coefficients are shown in Table 2. Diet had a significant (P < 0.05) effect on digestibility of dry matter (DM), energy, protein and crude fibre, while period, animal and sex did not (P > 0.05). The digestibility coefficients of DM were 95.3, 92.6, 93.7 and 92.3 for Diets I, II, III and IV respectively. Digestibility of energy followed a similar trend. Energy digestibility coefficients in diet I and IV were similar and lower than those of diets II and III (Table 2). Diet III had the highest energy digestibility (P < 0.05). This diet was composed of maize and sorghum in equal proportions. This observation was at variance with previous reports which indicate that sorghum based diets have lower digestibilities (Cousins, 1979; Hansen et al., 1993). Diet III had 2.4% lard and fats are known to improve energy digestibility and utilization (Chen and Yen, 1994).
Table 2. Latin square ANOVA mean squares and the apparent digestibility coefficients of dry matter, gross energy, crude protein and crude fibre.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>DM</th>
<th>GE</th>
<th>CP</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period</td>
<td>3</td>
<td>0.9</td>
<td>0.1</td>
<td>16.3</td>
<td>71.7</td>
</tr>
<tr>
<td>Animal</td>
<td>7</td>
<td>1.1</td>
<td>4.3</td>
<td>16.4</td>
<td>28.7</td>
</tr>
<tr>
<td>Diet</td>
<td>3</td>
<td>0.3</td>
<td>37.0*</td>
<td>382.9*</td>
<td>694.0*</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>2.9</td>
<td>0.2</td>
<td>5.8</td>
<td>51.4</td>
</tr>
</tbody>
</table>

**digestibility coefficients**

<table>
<thead>
<tr>
<th>Diet</th>
<th>DM (%)</th>
<th>GE (%)</th>
<th>CP (%)</th>
<th>CF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize/soybean diet</td>
<td>95.3*</td>
<td>78.2*</td>
<td>85.9*</td>
<td>60.1*</td>
</tr>
<tr>
<td>Maize/CSC/SFC Diet</td>
<td>92.6c</td>
<td>80.3ab</td>
<td>76.2b</td>
<td>42.3b</td>
</tr>
<tr>
<td>Maize &amp; sorghum Diet</td>
<td>93.7b</td>
<td>81.8b</td>
<td>73.8b</td>
<td>43.6b</td>
</tr>
<tr>
<td>Sorghum/CSC/ SFC Diet</td>
<td>92.3c</td>
<td>76.9a</td>
<td>69.6c</td>
<td>39.6b</td>
</tr>
</tbody>
</table>

**Notes:**

* significant F (P<0.05)

Means with different letter superscripts are significantly different (P<0.05) (Scheffe F-test).

DM - Dry matter
GE - Gross energy
CP - Crude protein
CF - Crude fibre
CSC = Cotton seed cake.
SFC = Sunflower seed cake.
However, diet IV had 3% fat but had a lower digestibility coefficient of energy which was an indication that something else was responsible for the higher digestibility of energy in diet III. Different sorghum varieties have varying levels of polyphenolic compounds called tannins that reduce palatability and digestibility. The tannin content of the Cerate variety of sorghum used in this study varies between 8 and 36 g/kg and this were negatively correlated with true metabolizable energy in poultry (Jacobs et al., 1997). If an average tannin content is assumed diets III and IV had 8.3 and 16.4 g/kg tannins. It is possible that the fat level in diet III overcame the detrimental tannin effects.

However, improvement of energy digestibility in sorghum diets mixed with other grains has been observed previously (Yamazaki and Kaku, 1988) and was attributed to the dilution of tannins in the gut thus reducing their detrimental effects. However, dilution effect cannot fully explain this observation because Diets I and II had no sorghum and yet had lower energy digestibility. It is probable that maize starch granules are able to replace tannins in binding sites of amylases. Once the granules are broken down, sorghum and maize starch granules as well as tannins would compete unequally for those sites. There is a possibility that some of the tannins would be precipitated by some of the protein or fibre in the diet. The fact that diet III had lower protein digestibility than diets I and II does indicate that some of the tannins were precipitated by the proteins. Maize and sorghum could have synergistic effects on enzymes that lead to increased energy digestibility. Thus diet I and IV based on maize and sorghum respectively do not have this advantage. Diet IV was disadvantaged
further because of its higher tannin content (table 1).

Crude protein digestibility was lowest (P<0.05) in the sorghum based diet (diet IV). A progressive (P <0.5) decrease in protein digestibility with increase in sorghum inclusion was observed in this trial. This could not be entirely due to fibre content as the fibre contents of diets II, III and IV were comparable (Table 1). It is possible that tannins could be responsible for the lower protein digestibility in this trial.

Utilization of energy from sorghum is lower (Cousins, 1979). In spite of reports of similarities in nutrient composition (Cohen and Tanksley, 1976) sorghum based diets always give poorer performances to maize. Differences in fibre protein matrices have also been blamed for the lower digestibility of energy and protein in sorghum (Hansen et al., 1993). The great variability of sorghum varieties and also within variety may be responsible for inconsistencies in performance reports (Lin et al., 1987).

Inclusion of soybeans as source of protein had a positive effect on digestibility of protein and fibre. The differences may have been due to the higher fibre contents of the diets II, III and IV. Dehulling reduces the fibre content of the cake and has been shown to improve energy and protein digestibilities (Leslie, Summers and Jones, 1973). Mitaru and Blair (1984) showed that diets containing higher fibre contents were less digestible for rats. However, these authors also detected a non fibre effect on the decreased digestibility. Superiority of soybean over cotton seed cake and sunflower cakes has been recorded (Krider, 1982; Ochetim and Attia, 1979; Wahlstrom et al., 1985) and is associated with higher fibre contents in cotton seed and/or sunflower seed cakes. It should be noted that, in this trial, fibre in diets II,
III and IV was less digestible. The maize / soybean diet had higher (P < 0.05) digestibility coefficient of fibre. It was apparent that addition of lard did not improve fibre digestibility of fibre in diets II, III and IV.

In conclusion, diets based on sorghum and cotton seed cake/sunflower mixture were shown to have lower protein and fibre digestibility. The sorghum diet was low in digestible energy but the diet composed of sorghum/maize mixture had the highest energy digestibility coefficient.
Chapter 4.

The effect of gestation and lactation feeding level on gilt weight gain, the products of conception and piglet performance, and on subsequent reproductive performance and carcass characteristics of primiparous sows.

4.1. Introduction.

Feed eaten by the sow during gestation is utilized for maintenance, growth, and deposition into the products of conception. Energy and protein requirements can vary widely with physiological stage, reproductive performance, behaviour and housing conditions. Low energy and protein diets cause protein catabolism in late gestation and poor piglet performance subsequently. The aims of good feeding are to achieve higher average piglet birth weight, higher piglet survival, higher weaning weights and shorten the weaning to oestrus interval. The energy reserves in gilts or sow at the beginning of the gestation vary. Most of the gain during gestation by the sow is in the abdominal muscle, The mammary glands, the reproductive organs and back fat. Loss in weight peripartum and in lactation follow the same order in reverse. Extreme loss in condition leads to inability to regain condition accompanied by reproductive failure. However, feed energy level has been implicated in causing failure to return to heat after weaning through an obscure mechanism. Possibilities of energy influencing pLH concentrations early in lactation have been raised which may influence return to heat after weaning.

The objectives of this trial were to study the effect of varying
plane of feeding sorghum based diets during gestation and lactation on:

a) sow’s change in weight during gestation and lactation,
b) the products of conception,
c) piglet performance to weaning,
d) the plasma levels of luteinizing hormone (pLH),
e) ovulation rates subsequent to weaning,
early embryo development in the subsequent gestation and,
f) sow carcass characteristics after 28 days of the subsequent gestation.

4.2. Materials and Methods.

4.2.1 Experimental animals.

A total of 21 gilts were used in this experiment. The experimental gilts were in two consecutive groups. The gilts were placed and fed in individual pens. The gilts in the first group (G1) were kept in group pen until after they were mated. Thus the G1 gilts were recruited into the experiment only after pregnancy was confirmed by failure to return to heat within 28 days of mating. Only ten gilts (bred at various weights and ages) in this group eventually came into the experiment. The gilts had no records previous to the experiment. This batch of gilts went through the experimental period of gestation, lactation, post-weaning period, rebreeding and slaughter.

The second group (G2) of gilts were bought in the early stage of gestation. The gilts were bred at 110 kg live weight. Their average age at mating was 270 days. Conception was confirmed at
source by failure to return to heat 19-23 days later. Eleven gilts in the G2 went through the experiment.

Gilts in both groups were weighed weekly throughout the experiment. On recruitment to the experiment, each gilt was fed either of the two planes of feeding (high or low plane allocated randomly at the start of the experiment) described below. The sows in each plane of feeding were assigned the high or low lactation feeding plane alternately as they farrowed.

4.2.2. The experimental diets.

In this trial two diets, one for gestation and one for lactation were formulated in accordance to NRC (1988) requirements. The energy densities were 14.2 and 14.6 MJ/kg DE and the protein contents were 14 and 15% CP respectively. The details of the gestation and lactation diets are shown in Table 3. Two levels of feeding during gestation and lactation were allowed. These levels of feeding were instituted 28 days after mating for the first group of pigs and 56th day of gestation for the second group of pigs. The high plane of feeding was rated at 29.9 MJ of digestible energy per day (2.1 kg) and the low level was rated at 14.2 MJ per day (1 kg) during gestation. After farrowing, the sows on each level were redistributed to two levels (high or low) of lactation diet as they farrowed starting with the high plane, then low, and so on. These treatments were instituted immediately after farrowing. The sows on the low energy levels were offered an additional 0.3 kg feed for each piglet on their litter while those on the high level were
Table 3. Composition of diets used in the feeding experiment.

<table>
<thead>
<tr>
<th>Ingredient (%)</th>
<th>Diets</th>
<th>Gestation</th>
<th>Lactation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum</td>
<td></td>
<td>73</td>
<td>66</td>
</tr>
<tr>
<td>Lard</td>
<td></td>
<td>3</td>
<td>4.5</td>
</tr>
<tr>
<td>Bone meal</td>
<td></td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Cotton seed cake</td>
<td></td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Sunflower seed cake</td>
<td></td>
<td>11</td>
<td>11.5</td>
</tr>
<tr>
<td>Limestone</td>
<td></td>
<td>1</td>
<td>1.25</td>
</tr>
<tr>
<td>Salt</td>
<td></td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Premix</td>
<td></td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Cost (Ksh/kg)</td>
<td></td>
<td>3.06</td>
<td>3.06</td>
</tr>
</tbody>
</table>

Calculated chemical composition of the diets.

<table>
<thead>
<tr>
<th>Moisture (%)</th>
<th>DE (Kcal/Kg)</th>
<th>Crude Protein (%)</th>
<th>Crude Fibre (%)</th>
<th>Crude Fat (%)</th>
<th>Calcium (%)</th>
<th>Available Phosphorus (%)</th>
<th>Lysine (%)</th>
<th>Methionine</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1</td>
<td>14.2</td>
<td>14.3</td>
<td>5.6</td>
<td>7.2</td>
<td>0.8</td>
<td>0.37</td>
<td>0.59</td>
<td>0.35</td>
</tr>
<tr>
<td>9.84</td>
<td>14.6</td>
<td>15.6</td>
<td>6.3</td>
<td>8.4</td>
<td>0.79</td>
<td>0.36</td>
<td>0.63</td>
<td>0.38</td>
</tr>
</tbody>
</table>
offered 0.5 kg more per each piglet in the litter. Thus, for a sow having eight (8) piglets, the energy intake was 84.1 and 49.4 MJ DE per day for the high and low planes respectively. After weaning the sows were fed 2 kg evenly on the lactation diet until they were re-bred, to prevent post-weaning dietary effects. After re-breeding the same level of feeding was sustained until the gilts were slaughtered about the 28th day of rebreeding. The gestation diet levels were instituted from the 28th day of gestation for the first batch of gilts. The levels of diet for the second batch of gilts were instituted as soon as the in-pig gilts arrived. This varied between 28th and 56th days of gestation. The reason for instituting these diets this late in gestation was to avoid the detrimental dietary effect on embryonic survival (Dyck and Strain, 1983; Varley and Prime, 1993).

Feed conversion was calculated using either of two methods:
a) The total amount of feed consumed was divided with the sum of litter weight at three weeks of lactation and sows' weight change and,
b) feed consumed to the end of lactation was divided with sum of litter weight at weaning and gain in sows' weight.

4.2.3 Blood sampling and pLH Assays.

Blood samples were collected from the sows during the lactation period beginning at the first week. Each week on a certain day, seven (7) blood samples were collected at intervals of thirty (30) minutes from each lactating sow. This was achieved by insertion of an in-dwelling cannula into the jugular vein (either
left or right) soon after farrowing to facilitate sampling. The end of the tube had a detachable cap through which 5ml of blood was drawn every thirty minutes for 3.5 hours each week. After blood sampling, the cannulae were flushed with heparinized normal saline. The samples were centrifuged and plasma stored at -20° C. A total of 162 samples were collected.

The plasma samples were assayed for porcine Luteinizing Hormone using a standard radioimmunoassay technique (Kraeling, 1982). The antibody to the hormone was raised in rabbit and the antibody to the first antibody was raised in goat. The radioactive marker used was Iodine-125. The whole assay was done in duplicates. The total, the blank, the reference counts, the standards and the high and low quality control tests took 20 tubes while the samples done in duplicates took 324 tubes making a total of 344 tubes. The intra-assay coefficient of variation (CV) for the standards and samples averaged 1.03% and 10.96% respectively. Results from 8 samples were excluded from analysis because of extreme intra-assay CV. The sensitivity of the assay was 0.35μg/l. The low and high quality control samples had CVs of 7.13% and 0.02% respectively and exhibited the parallel curve pattern to the standard curve. All the samples were analyzed in one assay so there was no inter-assay variation.

4.2.4. Weaning and remating.

Weaning was done after the piglets attained the age of four weeks (28 days). The sow was moved from the piglets and taken to the group pen. The group pen was far enough from the weaned
piglets to minimize both piglet and sow distress. Her feed allowance was reduced to 2 kg daily but still group fed in two meals. A junior boar was brought to the pen twice daily to check for heat and any sow on heat was taken to the senior boar mated and the event recorded. She was then moved to another group pen to await slaughter after confirmation of pregnancy (by failing to return to heat 18-23 days after mating).

4.2.5. Slaughter.

All the sows in the experiment were eventually slaughtered, about 28 days after mating and having failed to return to heat between 18th and 23rd day of mating. After being slaughtered the carcass was partitioned as follows:- The mammary glands were detached by carefully making parallel cuts on either side and undermining the connective tissue between the mammary tissue and the external abdominal muscles and then weighed. A longitudinal cut was made on the thorax and the abdomen along the median axis, the sternum was split and the visceral organs removed in one mass from the tracheo-oesophageal attachment on the throat distally to the perineum and weighed. The head was cut off and weighed. The feet were severed at the carpal and tarsal joints and weighed together. The carcass was then split by cutting through the backbones. A calliper was used to take the back-fat thickness at the shoulder just proximal to the scapular attachment, the loin at the last rib and at the ilia-sacral junction. Each half of the carcass was then weighed. The reproductive system was detached from the other visceral organs from the vulva proximally to the ovaries as a whole
and placed in a labelled plastic bag and kept safely in a refrigerator. Subsequently, the ovaries were detached, weighed and the number of corpora lutea counted and then excised and weighed. The uterus was detached, weighed and then opened from the proximal end of each horn. Each foetal package was removed in one whole piece and then punctured and all the foetal fluid collected in a beaker. The volume of the fluid was read using a measuring cylinder. The remainder foetal membranes and the foetus were weighed together and then the foetus was removed from the membranes and weighed. The weight of the foetal membranes was then calculated by difference. The sum of the weights of the foetuses and volume of foetal fluid (1 ml of the fluid was assumed to weigh 1 g) was deducted from the uterus weight to get the weight of the empty uterus.

4.2.6. Experimental design, Data preparation and statistical analysis.

A cross over design with animals nested within gestation diets was used in this experiment. The level of diet effect applied to two groups of gilts replicated consecutively was tested by a two way ANOVA with the interaction between the gestation and lactation levels testing the combined effect.

The data was entered into a spreadsheet database. The percent change of weight between the current weight and the initial weight was calculated to eradicate initial weight variance. Overall descriptive statistics (means, standard deviations, standard errors) were calculated using in-built spreadsheet functions. One-
Two-way analysis of variance was used to test for percent change in weight from onset of the experiment to farrowing, total litter size, number born alive, % stillbirth, litter weight and average piglet weight at farrowing between groups. The following reproductive performance parameters were also treated as above:

a) length in days of the wean to oestrus period (adjusted for the length of the lactation period).

b) Proportionate variables of the sow at slaughter.
   i) percent dressed weight.
   ii) percent mammary gland weight.
   iii) reproductive organs as a percentage of the carcass as well as the visceral organs.
   iv) back fat thickness at slaughter at the first and last rib and at the ilio-sacro junction.

c) resultant reproductive variables
   i) ovulation rates.
   ii) conception rates.
   iii) volume of the allantoamnion sacs collectively and weighted against foetal number.
   iv) weight of the foetal membranes (placenta) weighted against the foetal number.
   v) foetal weight.

d) relationships between concentrations of plasma pLH concentration and the dietary levels, the wean to oestrus period and the resultant reproductive variables.

Two-way ANOVA for the variables was calculated using the program
Statistx version 4.1e (Analytical Software, 1994). Least square regression analyses and correlation analyses were carried out by the same program.

4.3. The Results and discussion.

4.3.1. Experimental animals.

There were 21 gilts in the experiment. All the gilts farrowed and went through the lactation period successfully. However, two sows died after weaning. Apparently they never recovered from the stress of lactation. They persistently lost weight and finally succumbed.

4.3.2. Weight gain during Gestation.

The weights of the gilts at the start of the experiment and at the end of the gestation broken down by the feeding levels are shown in Table 4. The relative body weight gains and the length of the gestation period are also shown. Gilts on the low level feed gained an average of 15.3 kg while those on high feeding levels had an average gain of 30.3 kg (P < 0.05). The difference in the weight of the products of conception between the two levels of feeding was not significant (P > 0.05). Both low fed and high fed sows had similar efficiency of conversion of the gestation feed to products of conception and maternal body (P > 0.05). Gain in gestation is usually due to products of conception and gain in maternal body (de Wilde, 1980; Shields et al., 1985). This gain is in form of increased protein deposition in the muscles of the abdomen, and fat in the back in addition to general growth in
growing gilts (Lodge et al., 1979). Most of the gain for the low fed group was mainly due to the products of conception as shown in Table 4. The actual gain of the maternal body was less than 20% in comparison with about 47% in the high fed group. The higher gains were of the same magnitude as those observed by Lodge et al. (1979) but lower than the range recommended by Verstegen et al. (1986) of 25 kg gain in maternal body. The low level fed gilts were lighter at farrowing but had consumed about half as much feed as the high fed group. Both groups had similar gains in form of products of conception and efficiency \( (P > 0.05) \). Many researchers have reported lack of improvement in efficiency emanating from pregnancy which would assist restricted feeding in achieving higher gains in gestation but rather that mobilization of body tissues takes place to support development of products of conception tissues. However, suggestions of better conversion by feed restricted sows during gestation (pregnancy anabolism) also abound. Wilde (1980a; 1980b) and Walachi-Janiak et al. (1986b) observed a marginal efficiency of feed restricted gilts in gestation and attributed it to differential deposition in tissues either in the products of conception or in the maternal body. Hovell et al. (1977), however, concluded that pregnancy anabolism does not exist and that advantages from underfeeding sows during gestation, if any, were short lived and non-existent at the end of the first week of lactation. In fact the high fed sows had a marginally better conversion efficiency. There was no difference in the length of the gestation length. Low and high fed groups had a gestation period of
Table 4. Sow performance during gestation and lactation.

<table>
<thead>
<tr>
<th>Gestation</th>
<th>Low</th>
<th>High</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number at start</td>
<td>11</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Number at farrowing</td>
<td>11</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Gestation length (days)</td>
<td>115.5</td>
<td>115.6</td>
<td>1.79</td>
</tr>
</tbody>
</table>

Average gilt weight during the gestation.

<table>
<thead>
<tr>
<th>At the start (kg)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediately* before Farrowing</td>
<td>111.41</td>
<td>104.7</td>
<td>19.69</td>
</tr>
<tr>
<td>Average gain (kg)</td>
<td>126.7</td>
<td>135.0</td>
<td>11.34</td>
</tr>
<tr>
<td>Immediately* after farrowing</td>
<td>115.9</td>
<td>120.6</td>
<td>10.8</td>
</tr>
<tr>
<td>Conception products**</td>
<td>12.6</td>
<td>14.4</td>
<td>7.2</td>
</tr>
<tr>
<td>Maternal gain (kg)</td>
<td>2.7</td>
<td>15.9</td>
<td></td>
</tr>
<tr>
<td>Feed consumed (kg)</td>
<td>115.5</td>
<td>242.8</td>
<td></td>
</tr>
</tbody>
</table>

Conversion Efficiency

| Feed/gain                        | 7.6  | 8.0  |      |

Weight change during lactation.

<table>
<thead>
<tr>
<th>Feeding level</th>
<th>LL</th>
<th>LH</th>
<th>HL</th>
<th>HH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Av. wt loss (kg)</td>
<td>16</td>
<td>17.1</td>
<td>11.2</td>
<td>1.9</td>
</tr>
<tr>
<td>wt loss/piglet weaned</td>
<td>2.2</td>
<td>2.4</td>
<td>2.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Av. Lact days</td>
<td>28.3</td>
<td>31</td>
<td>32</td>
<td>31</td>
</tr>
<tr>
<td>Feed eaten (kg)</td>
<td>91.4</td>
<td>187.3</td>
<td>85.4</td>
<td>182.5</td>
</tr>
<tr>
<td>Feed eaten/kg lost</td>
<td>5.7</td>
<td>10.9</td>
<td>7.2</td>
<td>15.3</td>
</tr>
</tbody>
</table>

SEM - Standard error of the mean
* Refers to either 1 week before or after farrowing maximum
** Piglets, foetal membranes and fluids.
" P < 0.05
115.5 and 115.6 days respectively.

4.3.3. Weight loss during Lactation.

The feed levels in lactation were nested within the gestation levels. Differences were observed in the weight loss between the two levels and also among the four resultant treatments and are shown in Table 4 (Low gestation level- low lactation level (LL); Low gestation level- high lactation level (LH); High gestation level- Low lactation level (HL); High gestation level High lactation level (HH)). The LL group lost an average of 16 kg; the LH group lost an average of 17.1 kg; the HL group lost an average of 11.2 kg and the HH group lost 1.9 kg (P < 0.05). So the sows fed low level in gestation collectively lost more (P < 0.05) weight during lactation than the sows fed high during gestation. The amounts of weight lost per piglet weaned were 2.2, 2.4, 2.6 and 1.6 kg for LL, LH, HL and HH respectively. The variation among treatments was not significant. The sows on low feeding level were able to use the feed offered more efficiently in conversion to piglets weaned (Table 4). The feed conversion to piglet growth at three weeks were 3.6, 7.9, 4.7 and 5.3 for LL, LH, HL and HH (P < 0.05). The figures suggested a greater efficiency for low fed sows. However, this did not put into account the mobilization of maternal body tissues to support piglet growth; in which case, the high fed sows had a marginally higher though non-significant efficiency. Weight loss during lactation is a function of breed, housing conditions and nutrition. Under optimal housing conditions (temperatures between 20-22°C) and nutrition weight loss in
lactation can be eliminated (Nielson and Danielson, 1983). The gain and loss, however, is relative as sows may actually lose fat and gain weight during lactation (Whittemore et al., 1980). The primiparous sows began the lactation at varying live weights (Whittemore and young, 1989) and lost weight to varying extent during the lactation. The gestation feeding had a carry over effect into the lactation with low fed sows losing more weight than the high fed group. It is significant that sows fed high in gestation and low in lactation lost much more weight than those fed at high level in both periods. The proportionate change over from high to low was more stressful to the sows in this group than to all the others and thus the group lost weight more persistently and did not recover after weaning (Table 7). The sow will mobilize body tissues (fat first then protein and ash if necessary) in order to synthesize sufficient milk for the piglets (Armstrong et al., 1986; King, 1987; Whittemore et al., 1989). The fat component is the most variable (Shields and Mahan, 1983). Tissue mobilization is inefficient and expensive energetically. Sows that proportionately gain much more fat than protein in gestation lose much more weight in lactation and this loss may continue even after weaning (Whittemore et al., 1989). In spite of losses of up to 25% live weight at parturition, the low-low fed sows in this trial started regaining weight after weaning which contrasted with the findings of Whittemore et al. (1989) but unlike in that report composition studies were not conducted. It is observed that from the onset of the lactation the sows fed low in gestation were accustomed to body
tissue mobilization. When these feeding levels were combined with piglet performance, average piglet growth of the low-low fed group was able to match that of the high-high fed group in providing adequate nutrition for the piglets. Nevertheless, the piglets of the low-low group out-performed those of the low-high (Table 5) and the high-low groups to the fourth week of lactation. This observation is of interest when viewed against that of the low-high group which lost most proportionate weight and still had least growth rates among piglets. The effects of sow mothering ability are significant to the third week and thereafter decrease rapidly as piglets become able to eat appreciable amounts of feed (Hovell et al., 1977). So the performance of the piglets at three weeks (Table 5) is a good indicator of how well the gilts converted the feed to piglet growth.

4.3.4. The products of conception and their post-farrowing performance.

All the sows in the experiment farrowed as expected with no variation in gestation length. The dietary treatments were applied 30 days after mating to eliminate dietary effect on embryo survival. The litter size in both groups were comparable though the high fed group had fewer piglets born alive and a relatively higher stillborn percentage. This variation was not expected as the high fed group received recommended levels of feed, and was borderline statistically (P = 0.0534 and 0.0885 respectively). The results of the gestation and lactation feeding levels on subsequent litter performance are shown in Table 5. Because of the slight litter
Table 5. Summary of the products of farrowing and their relationship to the gestation and/or lactation levels of feeding.

<table>
<thead>
<tr>
<th>Gestation levels of feed.</th>
<th>Low</th>
<th>high</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Litter size</td>
<td>9.5</td>
<td>8</td>
<td>2.1</td>
</tr>
<tr>
<td>Number born alive</td>
<td>8</td>
<td>5.8</td>
<td>2.5</td>
</tr>
<tr>
<td>Percentage stillborn</td>
<td>14.6</td>
<td>30.5</td>
<td>20.3</td>
</tr>
<tr>
<td>Av. Litter weight (kg)</td>
<td>12.0</td>
<td>9.7</td>
<td>3.0</td>
</tr>
<tr>
<td>Average Piglet wt (kg)</td>
<td>1.3</td>
<td>1.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Performance at 3 weeks after farrowing

<table>
<thead>
<tr>
<th></th>
<th>LL</th>
<th>LH</th>
<th>HL</th>
<th>HH</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Av. Litter weight (kg)</td>
<td>19.6</td>
<td>17.3</td>
<td>13</td>
<td>26.5</td>
<td>7.9</td>
</tr>
<tr>
<td>Average Piglet wt (kg)</td>
<td>2.7</td>
<td>2.4</td>
<td>2.3</td>
<td>3.5</td>
<td>0.4*</td>
</tr>
<tr>
<td>Feed per kg piglet</td>
<td>3.6</td>
<td>7.9</td>
<td>4.7</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>Feed per kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(piglet + sow gain)</td>
<td>18.3</td>
<td>10.2</td>
<td>9.7</td>
<td>14.5</td>
<td></td>
</tr>
</tbody>
</table>

Notes:

LL - Low level of feed in gestation and lactation
LH - Low level of feed in gestation and High in lactation
HL - High level of feed in gestation and low in lactation
HH - High level of feed in gestation and lactation
SEM - Standard error of the mean

Notes:

* P < 0.05
size advantage, the low fed gilts had a marginally higher litter weight. There were no differences in piglet weight and so the higher feed level did not result in heavier piglets (P > 0.05).

The advantage in litter weight at farrowing had disappeared by the third week of lactation (P > 0.05) though there was a mixed response in terms of average piglet growth (P < 0.05). Sows fed low level of feed in gestation and sustained on low feed level in lactation had a better piglet performance than those whose feeding levels switched either from high to low or from low to high. Sows sustained on the high level of feeding yielded the best piglet growth (Table 5).

The sows on the higher feed levels were less efficient in feed conversion to piglet growth or both piglet growth. The sows on the low feed level lost more weight but still used the feed more efficiently in piglet growth (P < 0.05). The least efficient group was the sows fed low level in gestation followed by high level in lactation and for all groups efficiency remained remarkably constant during the lactation (Table 4 and 5). However, some improvement in efficiency for the HL group was noted towards the end of the lactation. At weaning, the piglets of the low fed sows had a lower average weight (P < 0.05) but those of the other groups had similar gains.

None of the recognized factors that influence litter size were at play in this experiment. All the gilts were of an extraction of large white and Landrace mix the two breeds having been interbred indiscriminately for a long time in Kenya and so breed effects
observed by Irgang et al., (1986), Hunter and Picton (1994) and White and Wheeler (1995) among others. The gilts were all about the same age (Clark and Leman, 1986) and parity was not an issue nor was the mating (Dewey et al., 1995) for the gilts were mated naturally using the same boars. Nutrition has been known to influence litter size when sows undergo nutrition stress early in gestation or have a carry over effect from previous parity or diets having specific deficiency such as biotin (Clark and Leman, 1986). The dietary treatments in this trial were instituted after one month to avoid affecting early embryo development. Even if there was a carry over effect nutritional stress before the experiment, it did not have any effect on litter size. The litter size in this experiment were similar to those reported in other studies in the past (Varley and Cole, 1976; Dewey et al., 1976). Litter weights and average piglet weight did not vary with gestation feeding level. The piglets were somewhat average in size (1.3kg), within the acceptable range and slightly heavier than those reported by Varley and Cole (1976). Feeding level in gestation has not been shown to influence piglet or litter weight in pigs (Gruenwald, 1974; Habicht et al., 1974; Varley and Cole, 1976). Average piglet weight is highly dependent on litter size. There were more piglets stillborn from the high fed group and though this difference was not statistically significant (P > 0.05) it causes concern. Stillborns arise from a variety of reason among which the most important is stress around parturition. None of the gilts were stressed any more than normal and none of the farrowings
required assistance.

The litter weight at three weeks of lactation is considered a good measure of sow’s mothering ability and also of milk production by the sow and has been used to assess effects of feeding levels on sow performance (Yang et al., 1989; Trottier and Easter, 1995). If the litter size is standardized, this would be a good measure. Otherwise the number of piglets suckling the sow confounds any possible conclusion from such results; in which case the average piglet weight would be a better measure though it still carries a certain degree of litter size effect.

For purposes of discussion the results were reduced to energetic terms of the energy put into the sow and the energy output in terms of kilograms of piglet weaned and the weight lost from the sow, reasonable comparisons may be feasible. The litter size in this study was not standardized but the sows and piglets were weighed each week. Thus it was possible to reduce the intakes during the gestation and lactation as well as the gains and losses to gross energetic terms using conversion values (12 MJ gross energy (GE) per kg gain) proposed by Whittemore and Yang (1989) (Table 6). Under-feeding in gestation followed by high level of feeding in gestation was found to be most inefficient. Sows having gone through restricted feeding in gestation had physiologically adjusted and prepared to carry through the reproductive responsibility at the expense of mobilizing their body tissue and by fuller utilization of energy from diet. When efficiency is viewed in isolation, gestation feeding is the most important
determinant because at weaning sows fed high in gestation had superior conversion efficiency and little difference between those fed high or low in lactation. Evidently the extra feed consumed in gestation despite its being utilized somewhat inefficiently was put to good use over the lactation. Yang et al. (1989) using a different approach showed that fat sows at the parturition were more efficient than thin ones. The sows were fed ad-libitum during lactation but intake was measured. None of the sows in parity one in that study could finish the 7 kg offered, so lactation nutrition as well as litter size were found to confound the results (Yang et al., 1989). High plane of feeding in gestation would be recommended in this case. However, high feeding has been associated with increased locomotive, peripartum disorders and longevity problems (Dourmad et al., 1994).

It may be concluded that under-feeding of gilts during gestation is detrimental to maternal body weight gain but does not affect litter size or weight in that gestation. Neither does it affect growth of piglets in the first three weeks of nursing. However, the effect of level of feeding during gestation is carried over to the lactation and beyond. Underfeeding gilts in gestation is detrimental to their productive life and thus lowers longevity.

4.3.5 Return to oestrus.

Three sows in the LL group and one sow in the HL group failed to come back to oestrus. The one sow in the HL group died before showing post-oestrus heat. After weaning, all the sows in the LH and HH groups started cycling 18.7 and 8.3 days respectively (Table 7).
Table 6. Energy intake and retention in sows and the products of conception during gestation and lactation.

<table>
<thead>
<tr>
<th>Feed level</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response from feeds consumed during gestation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy intake (MJ DE)</td>
<td>1643.1</td>
<td>3454.0</td>
</tr>
<tr>
<td>Total weight sow gain (MJ GE)</td>
<td>54.0</td>
<td>172.8</td>
</tr>
<tr>
<td>Litter weight at farrowing (MJ GE)</td>
<td>114.0</td>
<td>92.2</td>
</tr>
<tr>
<td>Energy retained (MJ GE)</td>
<td>168.0</td>
<td>265.0</td>
</tr>
<tr>
<td>Energy consumed/energy gain</td>
<td>9.8</td>
<td>13.0</td>
</tr>
<tr>
<td>Response from feed consumed during lactation disregarding intake during gestation.</td>
<td>LL</td>
<td>LH</td>
</tr>
<tr>
<td>Total energy intake (MJ DE)</td>
<td>1300.2</td>
<td>2664.5</td>
</tr>
<tr>
<td>Total sow weight gain (MJ GE)</td>
<td>-192.0</td>
<td>-205.2</td>
</tr>
<tr>
<td>Litter gain at weaning (MJ GE)</td>
<td>221.4</td>
<td>267.9</td>
</tr>
<tr>
<td>Energy retained (MJ GE)</td>
<td>29.4</td>
<td>62.7</td>
</tr>
<tr>
<td>Energy feed/energy gain</td>
<td>44.3</td>
<td>42.5</td>
</tr>
<tr>
<td>Response from combined feed intake during gestation and lactation</td>
<td>LL</td>
<td>LH</td>
</tr>
<tr>
<td>Total energy intake</td>
<td>1943.3</td>
<td>4307.6</td>
</tr>
<tr>
<td>Net Energy (gain) (MJ GE)</td>
<td>83.4</td>
<td>116.7</td>
</tr>
<tr>
<td>Energy feed/energy gain</td>
<td>23.3</td>
<td>36.9</td>
</tr>
</tbody>
</table>

Notes:
- LL- Low level of feed in gestation and lactation
- LH- Low level of feed in gestation and High in lactation
- HL- High level of feed in gestation and low in lactation
- HH- High level of feed in gestation and lactation
1 kg gain is equivalent to 12MJ gross energy
The average length of the weaning to remating period for the LL and HL (calculated only for the sows that came back) was 16 and 17.6 days. The differences observed among groups after removal of those that failed completely to come back to oestrus were not significant (P < 0.05).

The return to oestrus post weaning should also be used in judging the feeding level for the sows (Coffey et al, 1994). The feeding level effect is mediated through loss of body weight in general (Baidoo, 1989; Elsely et al., 1968) and body fat loss in particular (Whittemore and Yang, 1989). Johnson et al. (1989) observed the loss in body fat but did not find that it had anything to do with oestrus. The loss of body weight explains only about 25% of variability in the wean to oestrus interval (Johnson et al., 1989). Other reports show possible confounders in plasma pLH level sometime from farrowing to oestrus (Shaw and Foxcroft, 1985; Edward and Foxcroft, 1983), photoperiodism (possibly associated with ambient temperatures) and, as a result of which, intake and a separate ambient temperature effect (Prunier et al., 1994). In this study sows fed high in gestation and lactation had an average of 8.3 days interval while all others averaged between 16 and 18.7 days. The differences among the four dietary treatments were not significant but noteworthy in that there was a graduated increase in number of sows successfully remated (25%, 50%, 60% and 100% respectively) (Table 7). Sows fed at a high level throughout came back to oestrus earlier compared to those on the other treatments. Thus, although the sows in the LL group were
regaining weight after weaning, it was not sufficient to recondition them to cyclicity while those whose planes crossed over LH and HL had problems adjusting hence the high failure of conception in spite of coming back to oestrus. At slaughter these sows were seen to have ovulated (evidenced by the presence of corpora lutea) but implantation had failed to take place. Corpora lutea life in sows can be extended beyond the 14 days by a single blastocyst that may eventually fail to implant (Wrathall, 1980). Such sows would fail to come back to oestrus as expected but come back from the 30th day. Since the sows were slaughtered 28 days after mating these were presumed pregnant on slaughter. In any case adequate energy must be put into pigs to facilitate continued reproductive function.

4.3.6 Plasma concentrations of porcine Luteinizing hormone (pLH). There was a consistent gestation feeding level effect on the plasma concentrations of pLH throughout the first three weeks of lactation that had sufficient samples analyzed. The fourth week did not have sufficient samples to make reasonable conclusions on. Table 8 shows the weekly means of the plasma concentration of luteinizing hormone in the first three weeks of lactation. Feeding level in gestation influenced pLH concentration positively in the first week of gestation but not thereafter. Because of the episodic release of pLH, averages of pLH at thirty minute intervals for each week are shown in chart form in Figure 1. The chart shows the trends observed as a result of the feeding levels in gestation. The major observation is that release of pLH in the first week of
Table 7. Summary of fate of the experiment animals during lactation.

<table>
<thead>
<tr>
<th>Lactation</th>
<th>LL</th>
<th>LH</th>
<th>HL</th>
<th>HH</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. at start</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>No. dead</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>No. at end</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

**Postweaning performance**

<table>
<thead>
<tr>
<th></th>
<th>LL</th>
<th>LH</th>
<th>HL</th>
<th>HH</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number weaned</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Number dead</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Number remated</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>wt change</td>
<td>5.5</td>
<td>5.3</td>
<td>-2.9</td>
<td>22.5</td>
<td>25.9</td>
</tr>
<tr>
<td>days to remating</td>
<td>16</td>
<td>18.7</td>
<td>17.6</td>
<td>8.3</td>
<td>14.7</td>
</tr>
<tr>
<td>Number conceived</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>conception rate</td>
<td>25</td>
<td>50</td>
<td>60</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
- LL - Low level of feed in gestation and lactation
- LH - Low level of feed in gestation and High in lactation
- HL - High level of feed in gestation and low in lactation
- HH - High level of feed in gestation and lactation
lactation and indeed throughout the lactation is largely dependent on level of feeding during gestation.

When stepwise regression of various variables of interest (Gestation feeding level, Lactation feeding level, week of lactation, ovulation rate, ovary weight, average corpus luteum weight and sample number) only gestation feeding level and ovary weight were retained in the model. The coefficient for gestation feeding level was 0.175 (P = 0.0011) and that of ovary weight was -0.021 (P < 0.05). The general coefficient was 0.791 (P < 0.05). These two variables explained only 8.5% of the variation in plasma pLH concentrations (R² = 0.086). Overall plasma pLH level also had a significant correlation with ovulation rate (r = -0.1589; P < 0.05) and a marginally non-significant association with ovary weight (r = -0.1447; P > 0.05). More correlation analyses on the level of pLH in the first week of lactation showed significant associations between pLH and foetal fluid volume (r = 0.43; P < 0.05) and placenta size (r = 0.31; P < 0.05) but only a marginal association with embryo weight r = 0.20; P > 0.05) at slaughter. The plasma concentrations of pLH among treatments were markedly distinct in the first week of lactation but thereafter were within the same margins though more or less varying. The low fed group in gestation which had lower pLH concentrations in the first week had concentrations comparable to those of the high fed group in the second and third week.

The great difference in plasma pLH concentrations observed in this experiment in the first week of lactation may have been due to
difference in body fat content, difference in the rate of fat gain in gestation or difference in the rate of fat loss in the first few days of lactation. Shaw and Foxcroft (1985) showed that pLH stimulation is necessary for the ovary to resume cyclicity after weaning and related pLH concentrations to the wean to oestrus interval. Edwards and Foxcroft (1983) had concluded that lack of pLH stimulation was responsible for the sow's lactation physiological anoestrus. Before that, Stevenson et al. (1981) had described suppression of pLH secretion in lactation. pLH was observed to be differentially suppressed on the basis of feeding level in this study in the first week of lactation. Suppression was not observed in the second and third week of lactation. The studies of Shaw and Foxcroft (1985) and Edward and Foxcroft (1983) had concentrated on the peri-weaning period and observed the build-up of plasma pLH concentration towards oestrus. On the basis of that, Foxcroft et al. (1987) suggested use of pLH concentrations in lactation for prediction of post-weaning oestrus. In this study, it was not possible to come up with prediction equation as the variability in return to oestrus was not significant and appeared to be related to feeding level during gestation and lactation than on pLH concentration either in the first second or third week of lactation. A significant proportion of the sows in the low gestation feed level failed to come back to oestrus and these had lower plasma pLH concentrations. Kirkwood et al. (1987) had also observed these low fed sows' failure to come back to oestrus. Still, pLH was associated with reproductive function in such other
Table 8. Effect of level of feeding during gestation and lactation on average weekly plasma concentration of Luteinizing hormone (micrograms/litre).

<table>
<thead>
<tr>
<th>Level of feeding</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response to feeding level in gestation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week 1</td>
<td>0.68</td>
<td>1.03</td>
</tr>
<tr>
<td>2</td>
<td>0.93</td>
<td>0.91</td>
</tr>
<tr>
<td>3</td>
<td>0.99</td>
<td>1.01</td>
</tr>
<tr>
<td>Response to feeding level during gestation and lactation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LL</td>
<td>0.36</td>
<td>0.76</td>
</tr>
<tr>
<td>LH</td>
<td>0.83</td>
<td>1.03</td>
</tr>
<tr>
<td>HL</td>
<td>1.11</td>
<td>0.87</td>
</tr>
<tr>
<td>HH</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 1. Effect of gestation feeding level on plasma pLH concentration during the first three weeks of lactation.
ways as ovary size and ovulation rate (negative correlation), placenta size and foetal fluids volumes (positive correlation). 

pLH secretion is either depressed by stress in some way, or has its activity on theca-interstitial and granulosa cells suppressed.

Viveiros (1991) demonstrated high concentrations of cortisol in follicles of gilts treated with ACTH and also showed increased aromatization by increasing androgen concentration in the follicles. Similar increases in aromatization had been obtained by use of increasing pLH and androgen concentration in pure cultures of granulosa cells (Tsang et al., 1985). It is possible then that the low pLH concentrations observed in low fed sows in the first week of lactation may have been a result of nutritional stress over the gestation. The stress caused increased plasma concentrations of cortisol which may have a negative effect on pLH synthesis. While the above does not explain the negative association with ovary size and ovulation rate, increased concentration of pLH may have laid a foundation for higher aromatization in the first postweaning oestrus. The higher oestradiol concentration helped in advancing the uterine environment, leading to earlier implantation, and therefore, better placentation in the high fed sows (Morgan et al., 1987; Xie et al., 1990). The end result was larger placentas which contained more foetal fluid. The advantage of having larger placenta and more foetal fluid at this stage of gestation is not clear. It may have been simply a result of better uterine preparation for the ensuing gestation. This would enhance embryo survival. If that advantage persisted over the rest of the
gestation then heavier piglets would be the result (Dwyer et al., 1992). It must be borne in mind that 50% of sows fed low in gestation that came back to oestrus failed to conceive probably due to a less advanced uterine environment. There were no gross uterine differences between the sows that failed to come back to heat and those that did but failed to conceive.

4.3.7. Observations made on slaughtered sows.

The means for dressed percentage, uterine data and other data collected at slaughter of the sows are shown in Table 9. The sows that were remated were eventually slaughtered after 28 days if they did not return to heat between day 18 - 23 after the mating. The dressing percentages were similar and random among the 4 groups of sows (P > 0.05). Empty uterine weight increased from the LL, LH, HL and HH treatments though the increase was not statistically significant. The cause of this variation was due to some of the sows on the Low gestation diets failing to conceive in spite of coming back to oestrus. The contents of the uterus, therefore followed a trend similar to the empty uterine weight above. Though this trend did not have a statistical significance (P > 0.05), marked differences (P < 0.05) among treatments were observed in the uterus weight expressed as a percentage of the sow’s dressed weight (Table 9). Proportions to the dressed carcass of various components were constant through the levels of feeding in gestation or lactation and even when crossed over. Though there were minor differences there was no detectable trend (P > 0.05). The dressing percentage, the head and feet as proportions of the
Table 9. Summary results of various measurements taken at slaughter of experimental sows.

<table>
<thead>
<tr>
<th>Treatments Measure</th>
<th>LL</th>
<th>LH</th>
<th>HL</th>
<th>HH</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dressing wt %</td>
<td>61.7</td>
<td>61.3</td>
<td>63.1</td>
<td>62.5</td>
<td>2.3</td>
</tr>
<tr>
<td>Uterus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empty wt (kg)</td>
<td>1.0</td>
<td>1.5</td>
<td>1.7</td>
<td>2.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Contents wt (kg)</td>
<td>0.7</td>
<td>0.9</td>
<td>1.7</td>
<td>2.1</td>
<td>0.9</td>
</tr>
<tr>
<td>% of dressed wt</td>
<td>7.8</td>
<td>10.6</td>
<td>13.3</td>
<td>16.6</td>
<td>5.6*</td>
</tr>
<tr>
<td>Ovary wt (g)</td>
<td>5.8</td>
<td>5.3</td>
<td>7.8</td>
<td>6.9</td>
<td>1.5*</td>
</tr>
<tr>
<td>Mamma wt (kg)</td>
<td>3.6</td>
<td>2.6</td>
<td>2.8</td>
<td>3.0</td>
<td>0.7</td>
</tr>
<tr>
<td>Back Fat Thickness (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip</td>
<td>1.6</td>
<td>1.1</td>
<td>1.4</td>
<td>2.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Loin (10th rib)</td>
<td>1.5</td>
<td>1.1</td>
<td>1.3</td>
<td>1.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Shoulder (2nd T. vertebra)</td>
<td>3.8</td>
<td>2.5</td>
<td>2.9</td>
<td>3.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Head %</td>
<td>10.2</td>
<td>10.8</td>
<td>10.4</td>
<td>9.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Feet %</td>
<td>2.6</td>
<td>2.8</td>
<td>2.6</td>
<td>2.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Kidney wt (kg)</td>
<td>0.47</td>
<td>0.58</td>
<td>0.35</td>
<td>0.60</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Notes:
- LL - Low level of feed in gestation and lactation
- LH - Low level of feed in gestation and High in lactation
- HL - High level of feed in gestation and low in lactation
- HH - High level of feed in gestation and lactation
- SEM - Standard error of the mean
- * - P < 0.05
dressed weight and the actual kidney weights were similar over the various feeding levels. Back-fat thickness did not vary by feed level either. Total carcass fat calculated using the formula of King et al. (1986) did not vary with the feeding level (P > 0.05). It was expected that if carcass fat had some influence on return to oestrus, ovulation rate and conception rates that some residual differences should be observed 28 days after mating. This was not unreasonable considering the observation of graded conception rates discussed above. Whittemore and Yang (1989) among others subscribe to the theory of requirement of a threshold body fat for resumed cyclicity. However, these results are more inclined towards those of Johnson et al. (1989) who concluded that metabolizable energy intake had more influence on return to oestrus than body fat percent. The results of this study did not find the theory of minimal threshold fat tenable. Changes in body composition other than fat have been suggested and these range from protein catabolism (Reese et al., 1982b) to proportionate change in some other body components yet to be described (Johnson et al., 1989). The changes occurring in the body between the time when glucose levels fall below normal, the mobilization of fat and fatty acid oxidation, and recovery or sustenance of tissue mobilization cause variation in chemical proportions in the body which affects the ovary, the hypothalamus and the hypophysis in some undefined manner. These effects influence gonadotrophin release. There is need to connect feeding level (ME intake) to body composition changes and their effects on the pituitary-ovary axis and to the
rest of the reproductive system. A question still remains, however, of the mechanisms of operation of the feeding level effects either long term or short term on reproduction.

Sows fed low in gestation had lower ovary weights at slaughter than those fed high (P < 0.05). The mamma weight at slaughter varied non-significantly. In way of comparison, there was very little variation in either the head weight or head weight as a percentage of dressed carcass weight (P > 0.05), feet weight as a percentage of dressed carcass weight (P > 0.05) or the kidney weight which was fairly constant (P > 0.05).

Back-fat thickness was measured at slaughter on the shoulder just proximal to the scapula attachment, the loin at the margin of the last rib and the hip at the ileum-sacral junction. The differences in the back fat thickness were not significant (P > 0.05), but the LL group had greater loin and hip back-fat thickness than the LH and HL group, and greater than the HH group at the shoulder.

The fat component of the sow's body is the most variable of all the tissues. It can change drastically in a period of a few days. The loss in weight in the first week of lactation is probably a case in point about body fat variability. It is possible that the rate of change in body fat at some specific physiological time may influence reproductive physiology in a way that is not yet understood to bring about the observed reproductive failure of the underfed sow.
4.3.8. Early Embryo development to the time of slaughter.

The effect of feeding level in the previous gestation influenced a number of parameters responsible for foetal growth (Table 10). The separate gestation feeding level influenced ovulation rate in the postweaning oestrus. The low fed sows had fewer ova released. These also had lighter ovaries. Similar observations were made for separate lactation feeding levels. The combined gestation and lactation levels analysis showed significant ($P < 0.05$) differences among the four treatments in ovary weights. The sows fed low in gestation and lactation had about 1.5 ova fewer ($P < 0.05$) than the other combinations. There appears to be much variation in ovary size in the scanty literature reports. The ovary weights in this study were within the ranges given by Andre et al. (1993) and Wu and Dziuk (1995). It is expected that the ovary that releases more ova should be slightly larger than its corresponding partner because of the greater number of corpora lutea that will be formed. This could be verified by the fact that the size of the corpora lutea were fairly uniform though the corpora lutea of the HH group were significantly lighter than those of the other three groups. It is also evident that the left ovary over the four groups on average yielded 1.4 fewer ova but had corpora lutea of similar weight to its right partner. The significance of ovary size in reproduction is elusive. There is no evidence that size is a determinant of the endocrine function of the ovary. The corpora lutea is necessary for maintenance of the products of conception. If weight is correlated to secretion and the exact role of the
Table 10. Effect of level of feeding on embryo weight, ovulation rates, placenta weights and foetal fluid volume.

<table>
<thead>
<tr>
<th>Response to feeding level during gestation</th>
<th>Low</th>
<th>High</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total embryo wt (g)</td>
<td>29.5</td>
<td>37.8</td>
<td>16.3s</td>
</tr>
<tr>
<td>Placenta weight (g)</td>
<td>26.7</td>
<td>35.2</td>
<td>15.2s</td>
</tr>
<tr>
<td>Embryo weight (g)</td>
<td>2.74</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Foetal fluid (ml)</td>
<td>102</td>
<td>163</td>
<td>67.7s</td>
</tr>
<tr>
<td>Ova released</td>
<td>13.6</td>
<td>14.2</td>
<td>2.9s</td>
</tr>
<tr>
<td>Corpus luteum wt (g)</td>
<td>0.51</td>
<td>0.49</td>
<td>0.1</td>
</tr>
<tr>
<td>Ovary weight</td>
<td>6.0</td>
<td>7.4</td>
<td>1.4s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Response to lactation feeding levels irrespective of previous level during gestation</th>
<th>Low</th>
<th>High</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total embryo wt (g)</td>
<td>29.9</td>
<td>38.9</td>
<td>16.1s</td>
</tr>
<tr>
<td>Placenta weight (g)</td>
<td>27.2</td>
<td>35.8</td>
<td>15.2s</td>
</tr>
<tr>
<td>Embryo weight (g)</td>
<td>2.01</td>
<td>3.21</td>
<td>1.4s</td>
</tr>
<tr>
<td>Foetal fluid (ml)</td>
<td>140</td>
<td>123</td>
<td>24.5</td>
</tr>
<tr>
<td>Ova released</td>
<td>6.4</td>
<td>7.2</td>
<td>2.8s</td>
</tr>
<tr>
<td>Corpus luteum wt (g)</td>
<td>0.56</td>
<td>0.49</td>
<td>0.1s</td>
</tr>
<tr>
<td>Ovary weight</td>
<td>7.0</td>
<td>6.8</td>
<td>1.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interaction of feeding during gestation and lactation</th>
<th>LL</th>
<th>LH</th>
<th>HL</th>
<th>HH</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total embryo wt (g)</td>
<td>23.0</td>
<td>34.4</td>
<td>33.0</td>
<td>42.7</td>
<td>15.6s</td>
</tr>
<tr>
<td>Placenta weight (g)</td>
<td>21.2</td>
<td>31.0</td>
<td>31.0</td>
<td>39.9</td>
<td>14.6s</td>
</tr>
<tr>
<td>Embryo weight (g)</td>
<td>1.85</td>
<td>3.42</td>
<td>2.1</td>
<td>3.0</td>
<td>1.4s</td>
</tr>
<tr>
<td>Foetal fluid (ml)</td>
<td>116</td>
<td>92</td>
<td>174</td>
<td>153</td>
<td>67.2s</td>
</tr>
<tr>
<td>Ova released</td>
<td>11.5</td>
<td>14.4</td>
<td>13.6</td>
<td>15</td>
<td>2.9s</td>
</tr>
<tr>
<td>Corpus luteum wt (g)</td>
<td>0.51</td>
<td>0.50</td>
<td>0.61</td>
<td>0.41</td>
<td>0.1s</td>
</tr>
<tr>
<td>Ovary weight</td>
<td>5.8</td>
<td>5.3</td>
<td>7.8</td>
<td>6.9</td>
<td>1.3s</td>
</tr>
</tbody>
</table>

Notes:
- LL- Low level of feed in gestation and lactation
- LH- Low level of feed in gestation and High in lactation
- HL- High level of feed in gestation and low in lactation
- HH- High level of feed in gestation and lactation
- SEM - Standard error of the mean
- (P<0.05)
products of the ovary endocrine activity (Adashi, 1994; Burger and Finlay, 1989; Babalola and Shapiro, 1988; Ying et al., 1987) during gestation were known it might help in explaining the differences in size. Definitely the ovaries have an important role in conception and this may explain the differential foetal growth and fluids volume observed in this study.

The placenta weight (total weight of all the foetal membranes) was lower (P < 0.05) in the low fed group by as much as 8.5 grams than in the high fed group. Gestation feed level did not influence foetal weight (P > 0.05). However, high fed groups during gestation had significantly (P < 0.05) heavier placenta and greater foetal fluid volumes (Table 10).

However, differences in foetal development between the lactation feed levels were more pronounced. The placenta weight and the embryo weight were higher (P < 0.01) in the high fed group than in the low fed group.

The reproductive parameters taken on slaughter of the sows indicated significant feeding level effect on reproduction. Sows on low feeding level during gestation had lower empty uterine weight, lighter uterine products and the uteri formed a smaller proportion of their dressed weight (P < 0.05). A progressive but non-significant increase in those parameters was observed as diets changed through LL, LH, HL and HH. The gain in uterine weight gives an indication of the preparedness for the uterus to carry out the function of host to the foetal development successfully. The differences in the uterine weight occurred earlier than expected as
the most significant growth in products of conception takes place later on in the gestation (Lodge et al., 1979). It is likely, therefore that the extra gain may have preceded implantation and was a reflection of the better nourished sow preparedness to host pregnancy. The fact that total embryo weight and average embryo weight were higher in the sows fed high in the previous gestation demonstrates a carry over effect from feeding level in one gestation to the next. The sows fed high in gestation but low in lactation were able to overcome this set back in gestation and compared favourably with those fed high throughout in terms of uterine weight at slaughter and embryo weight. It is therefore credible that the uterus was set to serve the products of next gestation. More evidence to support that hypothesis may be adduced in form of better placentation observed by the 30th day in sows fed high in the previous gestation. The sows in all groups, in this experiment, had heavier placentas than those observed at an equivalent period by Hunter and Picton (1995), White and Wheeler (1995) and Wu and Dziuk (1995). Faster placental development enhances foetal development and placentas of larger sizes are associated with larger foeti (Dwyer et al., 1992; Wotton et al., 1977). In agreement with above statement, foeti in this study were heavier than those reported by Hunter and Picton (1995) in concordance with their heavier placenta. However, there were no differences in average embryo weight, so the difference in total embryo weight was due to the difference in embryo number.

It is uncertain what purpose extra foetal fluid would serve
this early in gestation. Because of having heavier (and therefore larger) placenta, individual foetus of high fed sows had a cushion of about one and a half times the volume of combined amniotic and allantoic fluids. The amniotic and allantoic fluid volume for sows on low feeding level was lower while that of sows on high level of feeding somewhat higher than those reported by Hunter and Picton (1995). Embryo survival has not been associated with changes in foetal fluid volume. Although little has been published on allantoic fluid volume, Knight et al. (1977) did describe a rapid increase in fluid volume between day 20 and 30 followed by a decrease to day 40 succeeded by a progressive increase to day 80 then a decrease to farrowing. The fluid volume observed by Knight et al. (1977) at day 30 of gestation were low and corresponded with those of embryo of the low fed sows in this study. Studies have been done in humans on the volume of amniotic fluid volume which is associated with the timing of parturition and baby distress at delivery (Fisk et al., 1990). There being no accurate method of measuring this fluids in-utero, measurements are taken peripartum and extrapolations made on the observations. Follow-up studies done in rabbits (Kizilcan et al., 1995), showed that low amniotic fluid volume was related to decreased post-partum lung volume and had higher proportions of lung hypoplasia. Similar observations had been made earlier in lambs (Scheerboom and Tavarine, 1985) and in kids (Harding et al., 1990). Studies by Trimmer et al. (1990) showed that both the foetus and the placenta play an important part in the regulation of the amniotic fluid
volume. It is important to understand how feeding level influences the foetal fluid volume especially in light of peripartum problems associated with high gestation feeding (Dourmad et al., 1994). It is probable that foetal fluid volume at partum plays a part in the most serious problem at farrowing, that is, stillborn piglets.

The combined gestation and lactation effect on the products of conception at slaughter was also studied and the results are presented in Table 10. The LL group had lowest placenta weight, embryo weight and ovulation rate. It had second lowest foetal fluid volume and ovary weight. The two middle groups LH and HL had comparable measurements for placenta weight but the LH group had the biggest foeti. The HH group had the biggest placenta and second largest foeti and fluid volume but the smallest sized corpora lutea. With exception of the ovulation rates, differences observed were significant ($P < 0.05$). Minor and small differences were observed between left and right uterine horns but this were random ($P > 0.05$). The means of the variation between horns are shown in Table 11.

In conclusion gilts fed low in gestation have lower plasma pLH concentrations in the first week of lactation but not in the subsequent weeks of lactation. As a result of being underfed in gestation and probably in relation to low pLH concentrations in the first week of lactation, gilts are more likely to fail to come back to heat and also to conceive if they do come back. Gilts underfed in gestation are likely to have poorer placentation manifested in lower placenta weights and foetal fluid volume in the subsequent
Table 11. Effect of the placement of embryos within the uterine horns on some measurements at slaughter.

<table>
<thead>
<tr>
<th>Horn of the uterus</th>
<th>Left</th>
<th>Right</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total embryo wt (g)</td>
<td>35.3</td>
<td>33.3</td>
<td>16.8</td>
</tr>
<tr>
<td>Placenta weight (g)</td>
<td>32.7</td>
<td>30.75</td>
<td>15.6</td>
</tr>
<tr>
<td>Embryo weight (g)</td>
<td>2.67</td>
<td>2.58</td>
<td>1.5</td>
</tr>
<tr>
<td>Foetal fluid (ml)</td>
<td>138</td>
<td>137</td>
<td>74.2</td>
</tr>
<tr>
<td>Ova released</td>
<td>6.1</td>
<td>7.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Corpus luteum wt (g)</td>
<td>0.51</td>
<td>0.49</td>
<td>0.1</td>
</tr>
<tr>
<td>Ovary weight (g)</td>
<td>6.6</td>
<td>7.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

SEM - Standard error of the mean
gestation. Feed variation affects reproductive organs (particularly the products of conception) more than it does other body organs.

General discussion.

Feeding of sensitive values of maize and sorghum diets.

Maize is used extensively in feeding pigs. Sorghums have also been used in some parts of the world as the major feedstuffs in pig feeds (Habek and Torksey, 1976). Energy digestibility was similar in maize and sorghum based diets. However, inclusion of maize in sorghum in equal proportions in diet III had a favourable effect on energy digestibility. The cannin effect may have been stimulant to have increased the rate of passage but inadequate to achieve this the energy digestibility. The protein and fibre content were decreased with inclusion of sorghum, probably due to the nature of diets in sorghum (Habek et al., 1976). Although maize and sorghum are expected to have similar nutrient composition, sorghum based diets are expected to have lower energy and protein digestibility (Habek, 1976). Apart from the differences in the fact that sorghum contains oxalates in sorghum are harder and more resistant to moisture penetration, may be responsible for the decreased digestibility (Chan et al., 1995). Maize has a lower variable content composition than sorghum (Lin et al., 1995). Since maize cannot be used alone as pig feeds but must be mixed with other ingredients in order to meet nutrient requirements, their
Chapter 6.

General discussion.

6.1 Evaluation of nutritive values of maize and sorghum diets.

Maize is used extensively in feeding pigs. Sorghums have also been used in some parts of the world as the major feedstuff in pig diets (Cohen and Tanksley, 1976). Energy digestibility was similar for both maize and sorghum based diets. However, inclusion of maize and sorghum in equal proportions (diet III) had a favourable effect on energy digestibility. The tannin effect may have been sufficient to have reduced the rate of passage but inadequate to interfere with the energy digestibility. The protein and fibre digestibility decreased with inclusion of sorghum, probably due to tannin effect or the nature of fibre in sorghum (Hansen et al., 1993; Cohen and Tanksley, 1976). Although maize and sorghums are always assumed to have similar nutrient composition, sorghum based diets are reported to have lower energy and protein digestibility (Cousins, 1979). Apart from the tannins effects, the fact that starch protein complexes in sorghums are harder and more resistant to moisture penetration, may be responsible for the decreased digestibility (Chen et al., 1995). Maize has a less variable nutrient composition than sorghum (Lin et al., 1987). Since sorghums cannot be used alone as pig feeds but must be mixed with other ingredients in order to meet nutrient requirements, their
slightly lower digestibility of energy and protein need not limit their use.

The CP and CF digestibility of soybean based diet was higher than those of cotton seed and sunflower seed cakes diets. Probably this was due to the lower fibre content of the soybean diet. It could also be due to the difference in the nature of the fibre. Protein fibre matrices in sunflower seed and cotton seed cakes are different (Hansen et al., 1993). This makes fibre and protein in cotton seed and sunflower cakes less digestible. Energy digestibility was similar for both Maize and sorghum based diets. However, inclusion of maize and sorghum in equal proportions (diet III) had a favourable effect on energy digestibility. The protein and fibre digestibility decreased with inclusion of sorghum, probably due to tannin effect or the nature of fibre in sorghum (Hansen et al., 1993; Cohen and Tanksley, 1976).

6.2 Effect of underfeeding on sows' and litter performance.

Gilts, apart from carrying the products of conception during gestation are expected to grow (Shields et al., 1985). The gilt's weight gain during gestation is in form of maternal protein resulting from growth as well as special deposition in the abdominal muscles. Fat is also stored in the back, but this is dependent on nutrition (Lodge et al., 1979). 47% of the gain in the high fed group was in form of maternal body while it formed only 20% in the low fed group. Neither group needed to mobilize body tissue to support the development of the products of conception though it has been reported to happen (Walachi-Janiak et al.,
1986b). However, varying level of feeding had no effect on overall efficiency of gain during gestation.

Level of feeding did not affect weight loss per piglet during lactation. However, sows on the high feeding level during gestation and low level during lactation lost most weight during lactation. Sows that gain more weight during gestation lose more weight in lactation. Excessive weight gain during gestation is stored as fat in the back (King, 1987; Whittemore et al., 1989) and is therefore easy to mobilize during lactation. Sows on low feeding level during both periods started regaining weight after weaning, an observation at variance to that of Whittemore et al. (1989).

Piglets of the sows on the LL regime of feeding grew better than those of the other regimes in the first week of lactation. However, this advantage was lost by the third week. It is possible that the low fed sows were able to mobilize body tissues to meet milk production requirements early in lactation when mothering ability is an important factor in piglet growth (Hovell et al., 1977). Physiologically, animals are able to adjust their metabolism to match energy intake. The low fed sows were in a position to take advantage of the increased energy intake during the first week of lactation due to the adjusted metabolism. Though the energy intake early in the lactation was still lower than recommended level, this was more efficiently converted to milk as evidenced by the faster growth of their piglets in the first week. No doubt this was enhanced by tissue mobilization. But this group was unable to sustain this advantage to weaning probably because of exhaustion.
(Trottier and Easter, 1995). Sows in the high feeding level during gestation had an overall better efficiency at the end of lactation. Changing to high level of feeding during lactation from low during gestation did not amend the gestation nutrition stress. It would have been expected, that the increased energy supply would have enabled the sows in the LH group to raise the piglets as well as those in the LL group without incurring similar tissue mobilization. As this did not happen, it can only be surmised that either the digestibility of the feed decreased (as is often observed when feed intake is increased in pigs) or their systems were unable to convert the extra energy to body fat as the systems were geared towards mobilization. This must have resulted in higher heat increment. It is probable that both this things happened.

Proportionately, sows fed low either during gestation or lactation had a poor return to oestrus record after weaning. These sows averaged a wean to remating period of seventeen days compared to the eight day period of the high fed sows. In addition, sows in groups HL and LH had proportionately more sows that returned to oestrus, ovulated but failed to implant than HH sows. The LL and the LH sows were lighter at the post weaning oestrus than at oestrus resulting in the previous gestation. The HL sows gained only 2kg compared to the HH sows’ 22kg. Between weaning and remating LL and HL sows were gaining weight albeit at different rates, though LH and HL sows were not. The LH sows were losing weight at a faster rate than the HL sows. It is probable that the
body fat proportion for the LL, LH and HL sows was below the acceptable threshold (Frisch, 1982; Prentice et al., 1995) for normal cyclicity, ovulation and conception. This possibility was not verified one month later at slaughter of the sows for back fat thickness did not vary among groups. However, all groups were regaining weight in the period preceding slaughter. Since implantation takes place on day 12 of oestrus, sows on the lower plane of nutrition may have had poorly coordinated ovarian and uterine preparatory stages leading to unrecognized pregnancy (Pope, 1988; Pope et al., 1990; Stroband and Van der Lende, 1990). As the only management factor for all the groups was feeding plane during gestation and lactation, variation in wean to oestrus period, proportionate return to oestrus and conception rates were observations of nutritional effect (Coffey et al., 1994). It is possible that the metabolism of nutrients takes time to adjust adequately for the centres responsible for the control of reproduction to sustain fertility. It is also possible that the change over in nutrition status of the sows was not overcome soon enough for implantation to take place in significant proportions of sows under the low feeding planes.

Feeding during gestation has influence on subsequent sow performance. It has a direct effect on feed intake and metabolism during lactation (Weldon et al, 1994). This effect and a yet to be elucidated gestation carry over effect influences ovarian function in general and follicular development in particular. A population of follicles is maintained in a state of readiness to respond to
gonadotrophin release at weaning (Britt et al., 1985). As lactation progresses, there is an increase in follicular size and a decrease in atresia. During this time pLH plays a significant role early in the lactation in preparation for future gestation (Foxcroft et al., 1987; Edwards and Foxcroft, 1983b). The levels of this hormone are low during this time due to the suckling/opiate inhibitory effect on the release of Gonadotrophin releasing hormone (GnRH) and reaches nadir before the fourteenth day of farrowing (Varley and Foxcroft, 1990). The granulosa cells have been shown to pLH dependent FSH receptors. Gestation feeding has a direct influence on pLH levels as shown in this study. Sensitization of the granulosa cells to FSH at weaning for the final follicular development is dependent upon adequate plasma levels of pLH which is affected by gestation level of feeding (Ainsworth et al., 1990). The variation in pLH in this study was most evident in the first week of lactation. The feeding level effect on pLH may have been due to total body fat content by the end of gestation, rate of fat gain or loss in gestation and lactation respectively. Catabolism of fat in sows has been shown to increase plasma levels of corticosteroids but decreased levels of insulin. Insulin has a direct effect on the follicular cells. Increased insulin reduces rate of atresia and causes increased oestradiol release (Varley and Foxcroft, 1990). Oestradiol is known to induce the well recognized positive oestradiol-pLH relationship at advanced stages of follicular development leading to the preovulatory pLH surge. The sows on the higher plane of feeding lost less weight and hence a
higher level of insulin may be assumed to result from reduced catabolism. The insulin effect on the follicles would then lead to higher levels of pLH resulting from intensified oestrogen release in the high fed sows. Low levels of pLH early in lactation have a negative effect on subsequent reproductive performance (Stevenson et al., 1981; Edwards and Foxcroft, 1983; Shaw and Foxcroft, 1985). Plasma pLH was correlated with subsequent ovulation rate, placenta size and average foetal fluid volume. This was due to its effect on follicular development. Thus sows that had higher levels of pLH had reduce follicle atresia and therefore more follicles matured to the graafian stage resulting in a higher cumulative total oestradiol release. This lead to better and earlier uterine and ovarian preparation for the sows given high level of feeding during gestation for the subsequent reproductive cycle.

The uterus weight expressed as a percentage of dressed weight increased progressively with the combined feeding levels in lactation. As result of higher oestrogens initially from the follicles, the embryos and finally from the placenta, there was proliferation of uterine secretory cells. Blood retention also increased due to arterial dilation and therefore the increase in uterus weight with levels of feeding. These preparations resulted in better placentation and higher uterine fluid volumes. The sows fed low in gestation had lower ovary weights and was consequential to the lower ovulation rate and therefore the number of corpora lutea.

Hence sows fed low in gestation had a lower ovulation rate,
lighter placentas, the foeti were shrouded in less foetal fluid in the subsequent reproductive cycle. However, the individual foetuses in sows fed high in lactation were heavier than those of sows in the low level of feed.
7. Conclusions.

1. The digestibility coefficients for protein and fibre decreased with increased inclusion of sorghum in diets. However, energy digestibility coefficient was not as adversely affected. The cotton seed and sunflower seed cakes based diets had lower crude protein and crude fibre digestibility coefficients than the maize/soybean control diet.

2. Under-feeding of gilts during gestation while limiting gilt growth did not affect litter size and subsequent litter performance. Subsequent improved feeding during lactation did not result in improved gilt performance. However, feeding level influenced energy retention and efficiency of utilization.

3. High fed sows during gestation had higher plasma pLH concentration during the first week of lactation and, higher ovulation and conception rates and better subsequent early embryo development.

4. Underfeeding of gilts during gestation exacts such stress on them as would be difficult to recover from even with markedly improved feeding. It is, therefore, not desirable.
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