

# NUTRITION REPRODUCTION INTERACTIONS IN FARM ANIMALS

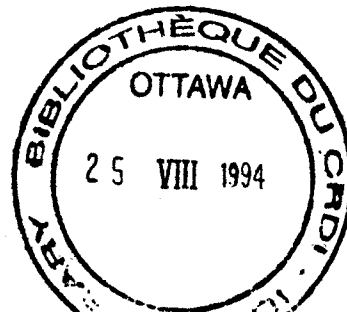
OLANREWaju B. SMITH<sup>1</sup> AND BABAJIDE SOMADE<sup>2</sup>

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<sup>1</sup> International Development Research Centre, Dakar Senegal.

<sup>2</sup> Obafemi Awolowo University, Ile Ife Nigeria.

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**NUTRITION REPRODUCTION INTERACTIONS IN FARM ANIMALS**

**O.B.SMITH<sup>1</sup> AND B.SOMADE<sup>2</sup>**

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<sup>1</sup> International Development Research Centre, Dakar Senegal.

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## **INTRODUCTION**

Livestock production efficiency or productivity is to a large extent dependent on reproductive performance. Thus, it has been suggested that in commercial beef cow-calf enterprises, reproductive performance is about five times more important economically than growth and ten times more important than product quality (Trenkle and Wilham, 1977). In subsistent extensive or nomadic cattle production systems common in the sahelian ecozones of Africa for example, the overall viability of the system depends largely on reproductive efficiency, to replenish the herd that is often decimated by harsh environmental conditions and diseases.

Several factors are known to affect the reproductive performance of farm animals, among which are biological type, the physical environment and nutrition. Proper nutrition could encourage mediocre biological types to reach their genetic potential, and may even alleviate the negative effects of a harsh physical environment. Poor nutrition on the other hand, will not only exacerbate detrimental environmental effects, but will also reduce performance below genetic potential. In other words, nutritional factors appear quite important in terms of their direct effects on reproduction, and the potential to moderate the effects of other factors. By the same token, they readily lend themselves to manipulation to ensure positive interactions.

The effects of nutrition on reproduction in farm animals have been documented by Topps (1977), Oyedipe *et al.* (1982), Vincent *et al.* (1985), Aherne and Kirkwood (1985), Short and Adams (1988), Hurley and Doane (1989), Leury *et al.* (1990), Robinson (1990) and Mcshane and Keisler (1991). These reports in general suggest that malnutrition resulting from inadequate, excess or imbalanced nutrients intake may delay puberty, reduce ovulation and lower conception rates, compromise embryonic and foetal survival, result in poor lactation, lengthen post partum anoestrus and reduce perinatal survival and performance.

This review will summarise available evidence on nutrition reproduction interactions in ruminants and pigs, with an overview of possible mechanisms through which nutritional effects are mediated, and suggest nutritional strategies to improve reproductive efficiency.

## **FEED, ENERGY AND PROTEIN INTAKE EFFECTS**

### *Puberty*

Dietary manipulations could be used to advance or retard puberty in both male and female livestock. Data on Table 1 (Den Hartog and van Kempen 1980) show a 9-day reduction in age at puberty in gilts, following a 34 % increase in energy intake. Precocious breeding is, however, to be avoided as this may on the long term compromise life time performance. Indeed, in most cases reported in the literature and in practice, dietary and energy restriction are used to delay the onset of puberty. In order to achieve significant and consistent delays in age at puberty in the pig, the feed or energy restriction need to be severe, about 50% of ad-libitum levels. This level of restriction according to Den Hartog and van Kempen (1980) may slow all somatic growth, and since general growth has priority over reproductive development for dietary energy, puberty will be delayed.

Less severe restriction above 60-70% of ad-libitum levels on the other hand, may result in variable effects as reported by Den Hartog and van Kempen (1980) who obtained delayed puberty in 2 , advanced puberty in 10 and no effect in 15 trials with pigs fed at this level of restriction. A similar variability was reported by Anderson and Melampy (1972) who obtained delayed puberty of about 16 days in 9 trials, but advanced puberty by an average of 11 days in another 5 trials. According to Robinson (1990), the effect of energy restriction on puberty may also be modified by the age of the animals. Apparently the effects are more pronounced when feed restriction is applied in early post natal than immediate prepubertal phase.

Weight is apparently the major factor affecting puberty in cattle. Thus restricted feeding that slows down growth will increase age at puberty. According to Topps (1976,1977), cattle grazing semi-arid tropical grasslands may on the average obtain only about 40-80% of their energy requirements from rangelands, and such restriction often result in delayed puberty of up to 9 months in heifers. A similar relationship between nutrition, growth and age at puberty reported in heifers is observed in the male (Robinson,1990).

A striking example was provided by Ketut et al. (1985) who reported that feed restricted Merino lambs did not attain puberty in their first potential breeding season, until the following year, when under more liberal feeding, the less restricted lambs growing at 130g/day reached puberty 4 weeks earlier and sustained higher sperm densities, than their counterparts growing at 80g/day during the realimentation period.

Inadequate protein intakes which occurs quite often in cattle grazing tropical and subtropical pastures with low protein content (<8%) have been shown to delay puberty. In an experiment comparing three levels of dietary protein treatments (8.3, 13.4 and 19.2%) in local Bunaji and Shokoto Gudali heifers, Oyedipe et al. (1982) reported a negative correlation between dietary protein levels and age at puberty, with age at puberty of 704, 640 and 570 days for the three groups respectively. A similar result was obtained by Rekwot et al. (1987) in Bunaji and Bunaji x Friesian bull crosses fed diets containing 8 and 14.5 % protein.

#### *Ovulation rate*

The technic of "flushing", that is, increasing feed or energy intake before mating in order to increase ovulation rate is a common management strategy in pig rearing, and is extensively documented in the literature (Anderson and Melampy, 1972, Den Hartog and van Kempen, 1980, Aherne and Kirkwood, 1985). There is general agreement in the literature that increasing energy or feed intake of gilts before mating will increase ovulation rate as shown in Table 2.

The data shows that increasing the daily ME intake from 21 to 34 MJ during the rearing phase increased average ovulation rate by 1.5, with a further increase of 1.8 during the oestral cycle when ME intake was further increased to 41 MJ daily. Variable results of flushing reported in the literature could be attributed to a timing problem. According to Aherne and Kirkwood (1985), the optimum period of increased energy intake appears to be in excess of 11 days before mating.

The effect may be positive or negative if increased energy intake occurs on the day before mating or on the day of mating, and no effect is noted if given on the day after mating. In addition, positive effects are more likely at the pubertal oestrus, rather than in the adult (Robinson, 1990).

This is in contrast to what obtains in the sheep, where according to (Hamra and Bryant (1982), the major long term nutritional effects on ovulation are seen in the adult rather than at pubertal oestrus, and are closely linked to their effects on body condition. Ovulation rate in ewes in good body condition as a result of proper nutrition is commonly high. Robinson (1990) noted that it is common for ewes grazing in the arid tropics to have less than 10% fat in the empty body weight and average ovulations of <1, while high plane feeding leading to 25% body fat doubles ovulation rate. Data published by Rhind et al. (1986) also demonstrated the link between body condition and ovulation rate, with ewes at 20 and 25% empty body fat averaging 2.3 and 3.4 ovulations respectively.

The effect of protein intake on ovulation rate in both ruminants and pigs is still equivocal. Aherne and Kirkwood (1985) reported that at protein levels between 12.5 and 16%, source and level of protein appear to have little effect on ovulation rate in the pig. Likewise, Robinson (1990) indicated that none of the studies on the effects of altering dietary protein levels, and amino acid concentrations in pig diets has resulted in enhanced ovulation rates above those of conventional diets.

In sheep, initial observations on responses to high protein supplements in the form of lupin grains 6-10 days before oestrus, suggested that high protein intakes may enhance ovulation rate (Oldham and Lindsay, 1984; Teleni et al. 1984). More recent studies, however, suggest that the specific protein effect is minimal (0.2-0.4), and similar to that seen in conventional flushing diets of short duration (Smith, 1988). This view is supported by recent findings showing that the observed ovulatory response to lupin grains is mediated by metabolic pathways involving the synthesis and/or utilisation of glucose (Teleni et al. 1989).

## *Pregnancy*

Nutritional effects on conception or fertilization rate, embryo and foetal growth and survival are reviewed under this heading. With the exception of ewes exposed to oestrogenic pastures, fertilization rates appear to be acceptably high even under diverse nutritional regimes (Mckelvey and Robinson, 1988). Nutritional effects on conception rate in the pig also appear minimal according to Aherne and Kirkwood (1985). This conclusion was based on evidence in the literature, including the reviews of Den Hartog and van Kempen (1980) of 26 experiments employing high and low feed intakes up to puberty or during the oestral cycle. In contrast, pre- and peri ovulatory as well as early pregnancy nutrition have significant effects on embryo survival. In a review of nutritional influences on embryo survival in sheep, cattle and pigs, Robinson (1986) concluded that extremes of nutrition in either direction, low or high plane, are detrimental to the growth and survival of the embryos in all three species.

Two interesting observations made by Robinson (1986) from an analysis of a number of studies on the effect of restricted feeding on embryo mortality in sheep are that embryos of young ewes and older ewes that are in poor conditions at mating are apparently at most risk from restricted feeding. Secondly that extended periods of restricted feeding, as low as 0.5 of maintenance level, can retard embryo development.

Two elegant studies by Mckelvey and Robinson (1986, 1988) involving the use of embryo transfer to examine the effects of diverse nutritional treatments during the first 60 days of pregnancy on embryo survival in the ewe, implied that high plane of nutrition in early pregnancy is detrimental to embryo survival. This observation linking overfeeding with embryonic mortality had been reported earlier by others in pigs (Dyck *et al.*, 1980, Aherne and Kirkwood, 1985, and confirmed in sheep (Parr *et al.* 1987). Data on Table 3 show a negative correlation between feed level and embryo survival on the one hand, and feed level and plasma progesterone on the other, suggesting that the effect of high plane of nutrition is mediated through a decrease in plasma progesterone.

This was confirmed by Parr *et al.* (1987) in ewes and Ashworth (1990) in gilts. They demonstrated that the detrimental effect of high plane feeding on embryo survival could be alleviated by the administration of exogenous progesterone. According to Parr *et al.* (1987), this effect of nutrition on plasma progesterone concentrations may be due to a higher clearance rate of progesterone since blood flow to the liver increases with feeding (Bensadoun and Reid, 1962) and the liver is the major site of progesterone catabolism (Bedford *et al.*, 1974).

In general, foetal growth places little demands for nutrients on the dam, and the required nutrients are easily met under normal feeding and production systems. Nevertheless extreme feed restrictions on the dam as sometimes observed under dry season grazing in the tropics, may compromise foetal growth and survival. Vincent *et al.* (1985) reported that restriction of feed intake to 15% of maintenance requirements from mating up to 60 days of gestation followed by realimentation at normal levels to the end of gestation in ewes that were in good body condition at mating, resulted in arrested growth of foetal tibial metaphyses and reduced lamb birth weight and viability. According to the authors, 42% of the lambs in the study were non viable due to growth retardation and low birth weight as a result of severe nutrient restriction to the dam. Although the restriction was removed at 60 days, the ewes had not reached their original mating weight by 100 days when foetal growth escalates, hence the resulting foetal growth retardation.

Additional evidence on the detrimental effect of maternal malnutrition on neonatal survival have been published by Reynolds *et al.* (1986); Alexander (1986). Maternal undernutrition apparently compromises neonatal survival through a reduction in the energy reserves of the offspring. In the lamb, body lipid constitutes 60-70%, while liver and muscle glycogen constitute about 15% of available energy between birth and suckling, and both reserves could be substantially reduced by underfeeding of the ewe (Alexander; 1986), in much the same way that the glycogen reserve in the piglet is reduced by restricted feeding in the sow (Seerley, 1989).



In addition to this depletion of newborn energy reserves maternal malnutrition compromises neonatal survival through its adverse effect on birthweight in the lamb. According to Alexander (1986), as birth weight decreases, the heat regulating mechanism of the lamb becomes less efficient, because the ratio between the surface area ( heat loss medium) and body weight ( heat production) increases, making the lamb more vulnerable to hypothermia in cold, and heat stress and dehydration in hot environments.

### *Post partum fertility*

Nutrition plays an important part in the initiation of post-partum ovarian activity in all farm species. From a nutritional stand point, the post partum period is a particularly difficult one for the animal, because of competition for nutrients by various physiological processes - lactation, uterine involution, maintenance of body condition, reinitiation of ovarian activity. If animals are poorly fed during this period as often occurs under tropical grazing systems, post-partum infertility, prolonged rebreeding intervals or nutritional anoestrus are the major consequences.

Considerable evidence exist that the observed nutritional effect on post-partum fertility is mediated through body weight changes, and Topps (1977) concluded that the more severe the undernutrition and weight loss in a herd or an animal, the lower the fertility and level of animal production. Recent evidence from studies with the pig has shown that sows that lose excessive amounts of live weight will have prolonged remating intervals and increased incidence of anoestrus ( King and Williams, 1984; Reese et al., 1984). Earlier work in cattle, by Richardson et al. (1976) showed a curvilinear relationship between body weight changes and calving percentage (Table 4).

Topps (1977) suggested that in order to fully elucidate the cause of infertility arising from undernutrition, far more needs to be known about the nature of the weight loss sustained under different conditions, since in times of severe losses, as experienced by cattle grazing medium to poor quality forages, valuable protein from the liver and muscle may be lost in addition to fat depletion.

Following critical analysis of results obtained from experimentation on feed restriction body weight losses and remating interval in the pig, Reese et al. (1984), and Kirkwood and Aherne (1985) postulated a physiological function for adipose tissue. Hence the need to relate nutritional effects to body composition changes rather than to body weight per se, more so in ruminants where gut fill may account for a significant part of body weight variations.

Body composition can not be used as a practical indicator of nutritional status, because of difficulty of measurements. It can, however, be easily and accurately estimated through the use of body condition scores. (Dunn et al. 1983; Houghton et al. 1990). According to the authors, body condition score (BCS) is a reliable method for estimating body composition, and can be used as a practical indicator of nutritional status and its effect on reproduction in the postpartum cow as shown in Table 5. Body condition scoring is by tactile and visual examination which can be easily carried out by a trained person without the use of any apparatus. It places the animal in a particular category according to condition ranging from very thin to excessively fat.

Prolificacy, that is, the number of viable offspring produced per year or per breeding life time is influenced by a number of factors such as ovulation rate, conception rate, embryo mortality, rebreeding interval etc. We agree with Topps (1977), that the level of post-partum fertility or the rebreeding interval is of paramount importance in determining reproductive efficiency. It therefore needs to be better understood, in order to further improve prolificacy in farm animals. Efforts need to be made therefore, to avoid detrimental nutritional effects which are well documented in the literature.

Aherne et Kirkwood (1985) summarised the outcome of a number of experiments in the literature on remating interval in energy restricted sows. The results (Table 6) show that increasing energy intake from a range of 26-33.6 MJ DE/day to 50 MJ ME/day, improved the remating interval. The authors pointed out that increasing the energy intake beyond 50 MJ DE/day resulted in little or no further improvement.

The adverse influence of energy restriction on post-partum fertility is not limited to pigs, as similar situations have been documented for cattle by Bellows et al. (1982) who observed it in cattle fed energy deficient diets, and by Rutter and Randel (1984) who fed diets deficient in both energy and protein.

One of the first studies to show a detrimental effect of protein on post-partum fertility in cattle when energy is adequate was by Sasser et al. (1988) who fed two groups of primigravid Hereford heifers (twenty each), isocaloric and energy adequate diets containing adequate (0.96) and deficient (0.32 ) kg protein per head daily respectively. The authors reported that the protein deficient diet lengthened the post-partum interval and decreased the number of females exhibiting oestrus, first service conception rate and overall pregnancy rate by 110 days post-partum. They attributed these results to: production of abnormal ova; a less favourable uterine environment (Ruder et al. , 1981); insufficient response of ovaries to gonadotropins (Jordan and Swanson, 1979); and/or reduced gonadotropins secretion (Rutter and Randel, 1984; Imakawa et al., 1986).

### **Mechanisms involved in nutritionally mediated effects on reproduction**

Evidence for the primordial role of nutrition on reproduction has been presented. Deficient and excess nutrient supply could be equally detrimental. Even nutritional treatments that result in highly desirable responses for one reproductive state may become counter productive in a subsequent phase, or for the reproductive economy of the animal as a whole (Robinson, 1990). Reviewed studies were more often than not equivocal in terms of the magnitude or even the direction (positive or negative) of nutritional effects on reproduction.

We have identified some of the factors responsible for this variability - severity of treatment, body condition of experimental animals, their age and reproductive status. A better understanding of the underlying mechanisms involved in these nutrition reproduction interactions, will probably shed some light on these variable and sometimes contradictory results. Advances have been made in this respect, but the mechanisms are not yet completely unravelled, perhaps because of the complex phenomena involved - complex neuro-hormonal reproductive dialogue, and the equally complex nutrient partitioning.

Some of the fundamental questions which many of the reviewed works attempted to unravel are: How do the various phases of the reproductive process respond to changes in nutrient supply? In other words, how do changes in nutrient supply to the organism alter, derange or promote reproduction, and its controlling mechanisms, and through which mediators. Do these mediators act directly on the gonads or via higher neural centres? In summarising responses to these questions, we adopt the strategy of briefly summarising the neuro-hormonal control mechanisms of reproduction, followed by a discussion of suggested nutritional modulation.

Reproduction is controlled by complex neuro-hormonal mechanisms built around the hypophyseal-pituitary-gonadal axis. GnRH is released in a pulsatile manner from the nerve terminals in the hypophyseal stalk-median eminence. These nerve endings impinge upon the hypophyseal portal blood system which supply the pituitary gland, and stimulate a pulsatile release of luteinizing hormone (LH), and follicle stimulating hormone (FSH) from the latter. Both LH and FSH stimulate the gonads which release steroids and inhibin which exert stimulatory and inhibitory effects on the pituitary (anterior), hypothalamus and high neural centres, to complete the neuro-hypophyseal-pituitary-gonadal axis.

Thus in the post-partum period, a rapid decrease in oestradiol after parturition removes the negative feed back on the hypothalamo-pituitary axis, promoting the synthesis/release of GnRH followed by increases in LH pulses, as well as release of oestradiol from ovarian follicles detectable in peripheral circulation.

Nutrition could modify these changes, and according to Robinson (1990), a common feature of these changes in all species, is the alteration in the frequency of the episodic release of LH. Gutierrez *et al.* (1987) reported that in undernourished and ovariectomised adult ewes, the pulsatile release of LH during anoestrus ceased when the ewes became emaciated, suggesting that the effect was mediated at the higher centres through mechanisms not involving the gonads. Reviewing the work of Day *et al.* (1986), who examined the effects of restricted energy intake in prepuberal heifers, Short and Adams (1988) concluded that the evidence suggested that restricted energy prevents or slows the maturational process at the pituitary-hypothalamus level.

This was confirmed recently by l'Anson *et al.* (1990), who investigated whether GnRH release is actively inhibited or not stimulated in growth retarded lambs. After treating the lambs with pentobarbital, a non specific neural inhibitor, they observed an increase in LH pulses, and concluded that the release of GnRh was actively inhibited. Other studies in pigs (Kirkwood *et al.*, 1987; cattle (Rutter and Manns, 1987) and sheep (Rhind *et al.*, 1989), have confirmed the evidence that undernutrition decreases circulating levels of gonadotropins by a direct inhibitory effect on the secretion of GnRH from the hypothalamus.

Evidence for a direct gonadal effect have been reported, however, by several workers who reported lower serum progesterone and/or reduced in vitro production by CL tissue of underfed animals ( Apgar *et al.*, 1975; Beal *et al.* ,1978; Imakawa *et al.* , 1983). The conclusion of Short and Adams (1988) after a review of the literature that after oestrus cycle the main effects of feed level seem to be on steroid production, and that the effects on steroid production are reflected back on the ability of the hypothalamus-pituitary to release gonadotropins , although there is some evidence that feed level acts directly on the hypothalamus-pituitary, reflect the lack of consensus in the literature.

Britt *et al.* (1988) , however, suggested that reproductive responses to changes in nutritional status fall into two categories: acute responses that occur within a few days such as increased ovulation rate associated with "flushing", and reduced embryo survival caused by overfeeding during the first two weeks of pregnancy in pigs; and chronic responses that occur after several days or weeks, such as delayed puberty and anoestrus. According to the authors, acute responses occur so quickly that there is usually no significant changes in body composition, while chronic effects are often associated with important shifts in body composition. Acute responses are therefore more likely to result in direct gonadal effects, while chronic responses necessarily implicate the higher centres.

### *Metabolic mediators*

Evidence exist in the literature that glucose is a specific mediator for the effects of energy intake on reproduction (Short and Adams, 1988). Indirect experimental evidence come from the feeding of monensin, an ionophore that increases feed efficiency in ruminants by increasing the production of propionate, the glucogenic fatty acid, in relation to acetate and butyrate. Thus, feeding monensin has been reported to decrease age at puberty (Mosely *et al.* 1982); and to reduce post-partum interval in thin cows (Randel, 1990). According to Rutter *et al.* (1983), these effects can be mimicked by infusing propionate into the rumen. Moreover, Randel (1990) suggested that increased gluconeogenesis resulting from increased propionate absorption is detected at the hypothalamic-pituitary-ovarian axis, leading to an increased release of GnRH and LH.

The use of 2-deoxy-glucose, a metabolic inhibitor of glucose to block oestrus and ovulation (Randel, 1990) constitutes another indirect evidence of the mediating role of glucose. Direct evidence has been presented by others (Garmendia, 1986; Richards *et al.* 1987) through glucose challenge or infusion experiments. Lemenager *et al.* (1991) identified some other neural transmitters including amino acids, insulin and insulin-like growth factors, and neuropeptides that may interact at higher centres to regulate reproduction, and presented some evidence of their involvement.

### *The role of micronutrients.*

Vitamins and minerals play essential roles in cellular metabolism, particularly as component parts of many enzyme systems. They are therefore indispensable for maintenance and growth, and therefore may indirectly affect reproduction. In addition they may directly influence reproductive function. Manganese, zinc, Molybdenum and beta-carotene, vitamin A precursor are all involved in steroidogenesis (Gawienowski et al., 1974; Hurley and Doane, 1989; Corah and Ives, 1991) Hurley and Doane (1989) also postulated that zinc may act through the pituitary to influence gonadotropic hormones secretion.

In recent studies on copper molybdenum interactions Phillip et al. (1987) postulated that the influence of molybdenum on reproduction is a direct effect upon the endocrine system, and not caused by decreased copper status. They concluded after an analysis of their results that molybdenum altered the release of LH and that it could have altered ovarian steroids secretion or the feedback of these steroids on the hypothalamic-pituitary system. Through appropriate dietary manipulation, these and similar effects may be exploited to improve reproduction, and a number of such manipulations have been reported in the literature.

Wilson (1966) reported that supplementing cows grazing manganese deficient pastures with 4 g of Manganese sulphate for 9 weeks starting three weeks before first service resulted in first service conception rate from 51 to 63%. In an experiment designed to determine the effect of amino acid chelated minerals on suspected cases of embryonic mortality in a dairy herd, Manspecker et al. (1989) supplemented a group of heifers with amino acid chelated minerals containing magnesium, manganese, iron, copper and zinc. They reported that while the control group of heifers had 20% confirmed embryonic mortality between 30 to 35 days, there were no confirmed cases of embryonic mortality in the supplemented group. In addition, conception occurred 45 days earlier in the supplemented heifers. A summary of reported role of micronutrients in reproduction is presented in Table 7.

### *Feeding strategies for improved reproductive performance*

Suggested strategies will focus mainly on ruminants, particularly those grazing poor tropical pastures. Under such conditions, a definite seasonality in quantity and quality of the fodder takes its toll on prolificacy. During the rains when pasture is abundant and of fairly high value, intake and digestibility are high enough to meet maintenance, growth and reproductive requirements.

During the dry season when only mature senescent material is available, both intake and digestibility are low, and available nutrients do not meet requirements of the animal, the ability of the animal to reproduce normally becomes compromised, unless the nutrient status of the animal is increased through supplementation. Figure 1 shows a schematised saw pattern of growth under such conditions, and the effect this may have on age at first breeding, as body weight determines this to a large extent.

Supplementary feeding could be in form of crop residues, hay or silage for energy, or protein concentrates, browse, and agro industrial by-products for additional protein. Given the demonstrated importance of micronutrients for reproduction, some form of mineral-Vitamin supplementation should be provided.

Some of the evidence presented in the literature shows that protein and energy supplementation of cattle grazing natural pastures during the dry season will improve fertility (Wiltbank *et al.*, 1962; Oyedipe *et al.*, 1982; Lee *et al.*, 1985). Nevertheless, providing a blanket supplementation to the herd as a whole is not recommended, and priority should be given to the most vulnerable animals. A lactating Bunaji cow weighing about 400-450 kg and producing about 5kg milk daily, would require much more energy to maintain her weight than if she were dry, hence lactating cows and their calves should have priority and be fed supplements generously, to meet their requirements. Other categories of animals - heifers approaching mating age and dry females need less or no supplementation, which should be targeted to the dry season.



## **CONCLUSION**

A great deal of information is available on the nature and extent of the interactions existing between nutrition and reproduction. Some of the information is contradictory, because we are dealing with a biological system that is prone to intrinsic variability. There are therefore, gaps in our knowledge on the nature of these interactions, but we have sufficient knowledge and information on important positive interactions and these need to be better exploited to improve the reproductive performance of our farm livestock.

## **REFERENCES**

Aherne, .X. and Kirkwood, R.N. 1985. Nutrition and sow prolificacy. J. Reprod.Fert.Suppl. 33:169-183.

Alexander, G. 1986. Physiological and behavioural factors affecting lamb survival under pastoral conditions. In: Factors affecting the survival of newborn lambs. Eds. Alexander G., Barker, J.D. and Slee, J. Lexemnoug; Commison of European Communities, pp 99-114.

Anderson, L. L. and Melampy, R.M. 1972. Factors affecting ovulation rate in the pig. In: Pig production, Ed. Cole, D. J. A. Butterworths, London. pp 329-366.

Apgar, J., Aspros, D., Hixon, J.E., Saatman, R. R. and Hanse, W. 1975. effect of restricted feed intake on the sensivity of the bovine corpus luteum to LH in vitro. J. Anim. Sci. 41: 1120-1123.

Ashworth, C. J. 1990. Effect of pre-mating nutritional status and post-mating progesterone supplementation on early pregnancy in large white gilts. Anim. Prod. 50: 560

Beal, W. E., Short, R. E., Staiggmiller, R. B.; Bellows, R. A., Kaltenbach, C. C. and Dunn, T. G. 1978. Influence of dietary energy intake on bovine pituitary and luteal function. *J. Anim. Sci.* 46: 181-188.

Bedford, C.A., Harrison, F.A. and Heap, R.B. 1974. the splanchnic, uterine, ovarian and adrenal uptake of progesterone and 20-alpha dihydroprogesterone in the pregnant and non-pregnant sheep. *J. Endocr.* 62: 277-290.

Bellows, R. A., Short, R. E. and Richardson, G. V. 1982. Effects of sire, age of dam and gestation feed level on dystocia and post-partum reproduction. *J. Anim. Sci.* 55: 18.

Bensadoun, A. and Reid, J. T. 1962. Estimation of rate of portal blood flow in ruminants: effect of feeding, fasting and anaesthesia. *J. airy Sci.* 45:540-543.

Britt, J. H., Armstrong, J. D. and Cox, N. M. 1988. Metabolic interfaces between nutrition and reproduction in pigs. In: Proceedings of the 11th International Congress on Animal Reproduction and Artificial Insemination. 5: 117-125. University College, Dublin.

Corah, L. R. and Ives, S. 1991. The effects of essential trace minerals on reproduction in beef cattle. *Veterinary Clinics of North America/ Food Animal Practice*, 7: 40-57.

Day, M. L., Imakawa, K., Zalesky, D. D., Kittok, R. J. and Kinder, J. E. 1986. Effects of restriction of dietary energy intake during the prpuberal period on secretion of luteinizing hormone and responsiveness of the pituitary to luteinizing hormone-releasing hormone in heifers. *J. Anim.Sci.* 62: 1641-1648.

Den Hartog, L.A. and van Kempen, G.J.M. 1980. Relation between nutrition and fertility in pigs. *Neth. J; agric. Sci.* 28: 211-227.

Dunn, T. G., Riley, M. L., Murdoch, W. J. and Field, R. A. 1983. Body composition and carcass energy content in post-partum beef cows. *J. Anim. Sci.* 57 (suppl 1): 391.

Dyck, G.W., Palmer, W. M. and Simaraks, S. 1980. Progesterone and luteinizing hormone concentrations in serum of pregnant gilts on different levels of feed consumption. *Can. J. Anim. Sci.* 60:877-884.

Garmendia, J. C. 1986. Secretion of luteinizing hormone in postpartum cows infused with glucose. PhD dissertation. Oklahoma State University, Stillwater, Okla.

Gawienowski, A. M., Stacewicz-Sapuncakis, M. and Longley, R. 1974. Biosynthesis of retinal in bovine corpus luteum. *J. Lipid Res.* 15: 375.

Gutierrez, J., Dunn, T.G. and Moss, G. E. 1987. Inanition decreases episodic LH release in ovariectomised ewes. *J. Anim. Sci.* 65 (suppl.1) : 406.

Hamra, A. M. and Bryant, M.J. 1982. The effects of level of feeding during rearing and early pregnancy upon reproduction in young female sheep. *Anim. Prod.* 34: 41-48.

Houghton, P. L., Lemenager, R.P., Moss, G.E. and Hendrix, K.S. 1990. Prediction of post-partum energy level and early weaning on reproductive performance of beef cows and preweaning calf gain. *J. Anim. Sci.* 68:1438.

Hurley, W.L. and Doane, R.M. 1989. Recent developments in the roles of vitamins and minerals in reproduction. *J. Dairy Sci.* 72: 784-804.

l'Anson, H., Wood, R. I., Bucholtz, D. C. and Foster, D. L. 1990. Pulsatile LH secretion is under active inhibition in growth-restricted female lambs in the absence of ovarian steroid feedback. *The Endocrine Soc. 72nd Ann. Meet. Abstr. #1473.*

Imakawa, K., Kittock, R. J. and Kinder, J. E. 1983. The influence of dietary energy intake on progesterone concentration in beef heifers. *J. Anim. Sci.* 56:454-459.

Imakawa, K. M., Day, M. C., Zalesky, D. D., Garcia-Winder, M., Kittok, R. J. and Kinder, J. E. 1986. Influence of dietary-induced weight change on serum luteinizing hormone, estrogen and progesterone in the bovine female. *Biol. Reprod.* 35: 377.

Jordan, E. R. and Swanson, L. V. 1979. serum progesterone and luteinizing hormone in dairy cattle fed varying levels of crude protein. *J. Anim. Sci.* 48: 1154.

Ketut-Sutana, I. and Edey, T.N. 1985. Reproductive development during winter and spring of Merion ram lambs grown at three different rates. *Australian J. Agri. Res.* 36: 461-467.

King, R. H. and Williams, I. H. 1984. The effect of nutrition on the reproductive performance of first litter sows. 1. Feeding level during lactation and between weaning and mating. *Anim. Prod.* 38: 241-247.

Kirkwood, R.N. and Aherne, F.X. 1985. Energy intake, body composition and reproductive performance of the gilt. *J. Anim.Sci.* 1518-1529.

Kirkwood, R. N., Baidoo, S. K., Aherne, F. X. and Sather, A. P. 1987. The influence of feeding level during lactation on the occurrence and endocrinology of the postweaning estrus in sows. *Can. J. Anim. Sci.* 67:405-415.

Lee, G. J., Hennessy, D. W., Williamson, P. J. Nolan, J. V., Kempton, T. J. and Leng, R. A. 1985. Responses to protein meal supplements by lactating beef cattle given a low quality pasture hay. *Aust. J. Agric. Res.*, 36: 729.

Leury, B.J., Murray, P.J. and Rowe, J.B. 1990. Effect of nutrition on the response in ovulation rate in Merino ewes following short-term lupin supplementation and insulin administration. *Aus. J. Agric. Res.* 41:751-759.

Manspeaker, J. E., Robi, M. G. and Edwards, G. H. 1989. Mineral nutrition and early embryonic mortality in the bovine animal. *The bovine practitioner*, 24: 154-156.

McKelvey, W. A. and Robinson, J. J. 1986. Embryo survival and growth in the ewe - recent studies on the effects of nutrition and on novel techniques for the recovery and transfer of embryos. In: *Annual Report of Studies in Animal Nutrition and allied Sciences*, Rowett Research Institute, 41:9-25.

McKelvey, W. A. and Robinson, J.J. 1988. The use of reciprocal embryo transfer to separate the effects of pre and post mating nutrition on embryo survival and growth of the ovine conceptus. In: *Proceedings of the 11th International Congress on animal reproduction and Artificial Insemination 2*, Paper no. 176. University College, Dublin.

McShane, Teresa M. and Keisler, D. H. 1991. Effects of dietary energy on ovarian function, estrogen suppression of luteinizing hormone and follicle stimulating hormone, and competency of the gonadotropin surge. *Biol. Reprod.*, 45: 486-492.

Mosely, W. M., Dunn, T. G., Kaltenbach, C. C., Hort, R. E. and Staigmiller, R.B. 1972. Relationship of growth and puberty in beef heifers fed monensin. *J. Anim. Sci.*, 55:357-362.

Oldham, C. M., and Lindsay, D. R. 1984. The minimum period of intake of lupin grain required by ewes to increase their ovulation rate when grazing dry summer pasture. In: *Reproduction in sheep*. Eds. Lindsay, D. R. and Pearce, D.T. Australian Academy of Science, Canberra. pp 274-276.

Oyedipe, E. O., Osori, D.I.K., Akerejola, O. and Saror, D. 1982. Effect of level of nutrition on onset of puberty and conception rates of zebu heifers. *Theriogenology*, 18: 525-537.

Parr, R. A., Davis, I. F., Fairclough, R. J. and Miles, M. A. 1987. Overfeeding during early pregnancy reduces peripheral progesterone concentration and pregnancy rate in sheep. *J. Reprod. Fert.* 80: 317-320.

Phillipo, M., Humphries, W. R., Atkinson, T. 1987. The effect of dietary molybdenum and iron on copper status, puberty, fertility and oestrus cycles in cattle. *J. Agric. Sci.*, 109: 321.

Randell, R. D. 1990. Nutrition and postpartum rebreeding in cattle. *J. Anim.Sci.*, 68: 853.

Reese, D. E., Peo, E. R. and Lewis A. J. 1984. Relationship of lactation energy intake and occurrence of post weaning estrus to body and backfat composition in sows. *J. Anim. Sci.* 58: 1236-1244

Rekwot, P.I., Oyedipe, E.O., Akerekola, O.O., Kumi-Diaka, J. and Umoh, J.E. 1987. The effect of protein intake on the onset of puberty in Bunaji and Friesian x Bunaji crossbred bulls in Nigeria. *Theriogenology*, 28: 427-434.

Reynolds L. P. Ferrel, C.L., Robertson, D. A. and Ford S.P. 1986. Metabolism of the gravid uterus, foetus and utero-placenta at several stages of gestation in cows. *J. Agric.Sci.* 106:437-444

Rhind, S. M., Leslie, I. D., Gunn, R.G. and Donney, J.M. 1986. Effects of high levels of body condition and food intake on plasma follicle stimulating hormone, luteinizing hormone, prolactin and progesterone profiles around mating in Greyface ewes. *Anim. Prod.* 43: 101-107.

Rhind, S. M., McMillen, S., McKelvey, W. A. C., Rodrigues-Herrejon, F. F. and McNeilly, A. S. 1989. Effect of body condition of ewes on the secretion of LH and FSH and the pituitary response to gonadotropin-releasing hormone. *J. endocrinol.* 120:497.

Richards, M. W., Wettemann, R. P. and Schenemann, H. M. 1987. Relationships between plasma glucose and insulin, and anestrus in nutritionally restricted beef cows. *Proc. Soc. Sec. Am.Soc.Anim.Sci.* p. 64. (Abstr).

Richardson, F. D., Oliver, J. and Clarke, G.P.Y. 1976. Analysis of some factors which affect the reproductivity of beef cows and of their calves in a marginal rainfall area of Rhodesia. 1. Factors affecting calving rate. *Anim. Prod.* 21: 41.

Robinson, J.J. 1986. Nutrition and embryo loss in farm animals. In: *Embryonic mortality in farm animals*. Eds. Sreemann, J. M. and Diskin, M. G.. Diskin Dordrecht: Marinus Nijhoff Publishers, pp 265-248.

Robinson, J.J. 1990. Nutrition in the reproduction of farm animals. *Nutrition Research Reviews*, 3:253-276.

Ruder, C. A., Sasser, R.G., Williams, R. J., Ely, J. K., Bull, R. C. and Butler, J. E. 1981. Uterine infections in the postpartum cow. 1. Effect of dietary crude protein restriction. *therigenology*, 15:561.

Rutter, L. M., Randel, R. D., Schelling, G.T. and Forrest, D. W. 1983. Effect of abomasal infusion of propionate on the GnRH induced luteinizing hormone release in prepuberalheifers. *J. Anim.Sci.* 56: 1167-1173.

Rutter, L. M. and Randel, R.D. 1984. Postpartum nutrient intake and body condition: Effect on pituitary function and onset of estrus in beef cattle. *J. Anim. Sci.* 58: 265.

Rutter, L. M. and Manns, J.G. 1987. Hypoglycemia alters pulsatile luteinizing hormone secretion in the postpartum beef cow. *J. Anim. Sci.* 64: 479-488.

Sasser, Garth R., Williams, R. J. and Bull, R. C. 1988. Postpartum reproductive performance in crude protein-restricted beef cows: return to estrus and conception. *J. Anim. Sci.* 66: 3033-3039.

Seerley, R. W. 1989. Survival and post weaning performance of pigs from sows fed fat during late gestation and lactation. *J. Anim. Sci.*, 67: 1889-1894.

Short, R.E. and Adams, D.C. 1988. Nutritional and hormonal interrelationships in beef cattle reproduction. *Ca. J. Anim.Sci.* 68: 29-39.

Smith, J. F. 1988. Influence of nutrition on ovulation rate in the ewe. *Aust. J. Bio. Sci.* 41: 27-36.

Teleni, E., Rowe, J.B. and Croker, K. P. 1984. Increased ovulation rates in ewes given infusion of energy-yielding substrates. *Proc. Nutr. Soc. Aust.* 9: 158.

Teleni, E., Rowe, J. B., Croker, K. P., Murray, P. J. and King, W. R. 1989. Lupins and energy-yielding nutrients in ewes. 2. Responses in ovulation rate in ewes to increased availability of glucose, acetate, and amino acids. *Reproduction, Fertility and Development.* 1: 117-125.

Topps, J.H. 1976. Effect of energy and protein deprivation on the performance of beef cattle. In: *Beef cattle production in developing countries*, Ed. Smith, A.J., Tonbridge Lewis Reprints Ltd.

Topps, J.H. 1977. The relationship between reproduction and undernutrition in beef cattle. *World Review of Animal Production*, XIII: 43-49.

Trenkle, A. and Wilham, R.L. 1977. Beef production efficiency. *Science* 198: 1009.

Vincent, I.C., Williams, H. and Hill R. 1985. The influence of a low-nutrient intake after mating on gestation and perinatal survival of lambs. *Br. vet. J.* 141:611-617.

Wilson, T. G. 1966. Bovine functional infertility in Devon and Cornwall: response to manganese therapy. *Vet. Rec.* 79: 562.

Wiltbank, J. N., Rowden, W. W., Ingalls, J. E.; Gregory, K. E. and Koch, R. M. 1962. Effect of energy level on reproductive phenomena of mature Hereford cows. *J. Anim. Sci.* 21: 219.



TABLE 1. Influence of energy intake of gilts during rearing on age and weight at puberty

Items	Energy Intake	
	Low	High
Starting age (days)	86.7	85.8
Starting weight (kg)	36.2	34.8
Mean energy intake (MJ ME/Day)	22.3	34.4
Age at puberty (days)	211.0	202.0
Weight at puberty (kg)	80.0	99.0

Source : Den Hartog and Van Kempen, 1980

TABLE 2. Influence of pre-mating dietary energy intake on ovulation rate in sows

Item		Period of feeding			
		Rearing		Oestrus cycle	
		Low	High	Low	High
Energy intake (MJ me/day)	1	21.2	33.8	22.5	41.1
	2	17.6	36.9	24.1	42.1
Ovulation rate	1	11.8 <sup>a</sup>	13.2 <sup>b</sup>	11.8 <sup>a</sup>	13.7 <sup>b</sup>
	2	13.8	15.4	11.6	13.4

a,b Within growing period, values bearing different superscript differ ( $P > .05$ ).

Sources : 1 Hertog and van Kempen, 1980

2 Anderson and Melampy, 1972

Table 3. Effect of feed restriction on plasma progesterone levels and embryo survival in sows

Feed level	Embryo Survival (%)	Plasma progesterone ng/ml
Low	82.8	16.7
Medium	78.6	13.8
High	71.9	11.8

Source : Dyck et al. 1980

TABLE 4. Relationships between body weight changes and calving percentage in feed restricted beef cows

Body weight change Early pregnancy to post-partum (%)	Calving percentage
- 28	0
- 24	55
- 20	46
- 16	82
- 12	82
- 8	91
- 4	87
0 + gains up to + 8	84

Source Richardson et al., 1976

Table 5. Five point body condition scoring (BCS) system for beef cattle

Group	BCS <sup>a</sup>	Description
Thin	1	<b>EXTREMELY THIN</b> with severe muscle wasting; may appear humped in the back with feet close together; usually weak; extremely prominent backbone, hooks, pins and ribs. Cows will have a long postpartum anestrus period and will have a difficult time conceiving during a limited breeding season at 60 to 90 days.
	2	<b>THIN</b> with little or no wasting of muscle structure; vigorous; little or no fat in rump, rib or brisket; prominent backbone, hooks, pins and ribs but normal appearing muscle structure. Cows will have a long postpartum interval; but if they do cycle during the breeding season, their fertility is high.
Optimum	3	<b>IDEAL CONDITION.</b> Thrifty with normal muscle structure; some evidence of fat deposition in the forerib, brisket and crops but limited around the tailhead; some smoothness over the shoulder, ribs, backbone, hooks and pins. Cows calving in this condition will have a shorter postpartum interval than thinner cows. Cows in this condition during the breeding season will optimize conception rate.
Fat	4	<b>FAT</b> but still firm; vigorous; considerable fat deposited over forerib; brisket protruding; tailhead full (bulging); very smooth over backbone with no skeleton visible except at hooks. Cows in this condition will have a short postpartum anestrus period, but conception rate is lower than with cows in ideal condition.
	5	<b>VERY FAT</b> with considerable softness; very fat over the forerib and shoulder; large prominent brisket; broad flat topline; large patchy fat deposits around the tailhead; body curvature becomes square in appearance. Cows in this condition will have a short postpartum anestrus period but will have a lower conception rate than thinner cows. Dystocia will be more of a problem with these cows.

Source: Lemenager et al. 1991.

TABLE 6. Influence of energy restriction on remating interval in sows

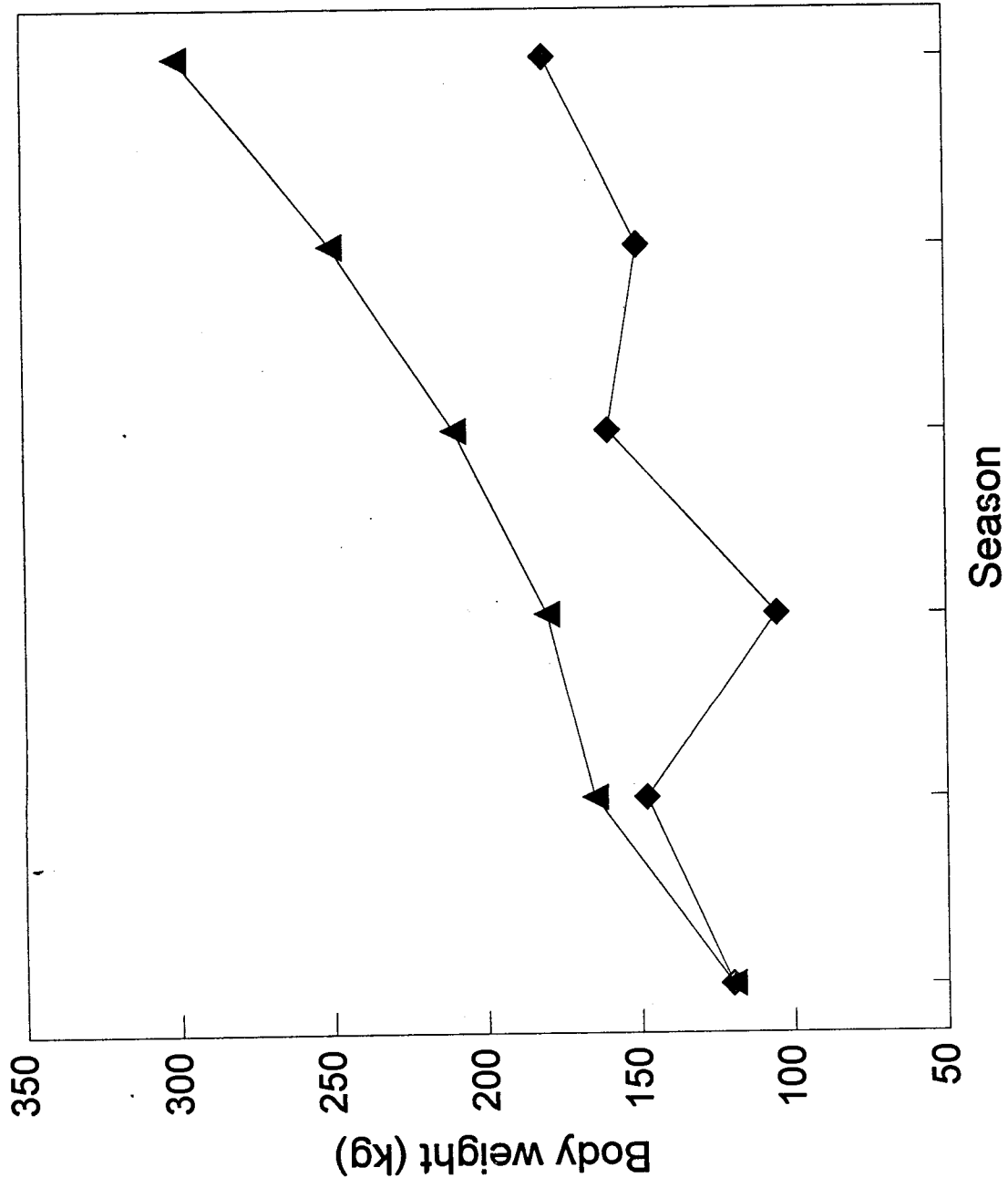
Energy intake (MJ ME/day)	% in oestrus by day 8	% in oestrus by day 14	% anoestrus on day 21
> 50	86.9	95.0	1.2
< 50	55.0	64.8	20.1

Source : Aherne and Kirkwood, 1985

TABLE 7. Role of micronutrients in reproduction

Micronutrients	Deficiency consequences
Vitamin A/Beta-carotene	Low conception rate, high perinatal mortality resulting from weak, blind, offspring, delayed puberty and reduced libido in the male.
Vitamin E/Selenium retained placenta.	Low fertilization rate and
Riboflavin	High embryonic mortality.
Folic acid	High embryonic mortality.
Phosphorus	Prolonged anoestrus, low conception rates and decreased fertility.
Copper	Decreased conception rate, anoestrus, fetal mortality and infertility.
Iodine	Silent oestrus, infertility, early embryonic mortality, high perinatal mortality. Depressed libido in males.
Zinc	Delayed puberty.
Manganese	Anoestrus, infertility, delayed puberty and low conception rate.

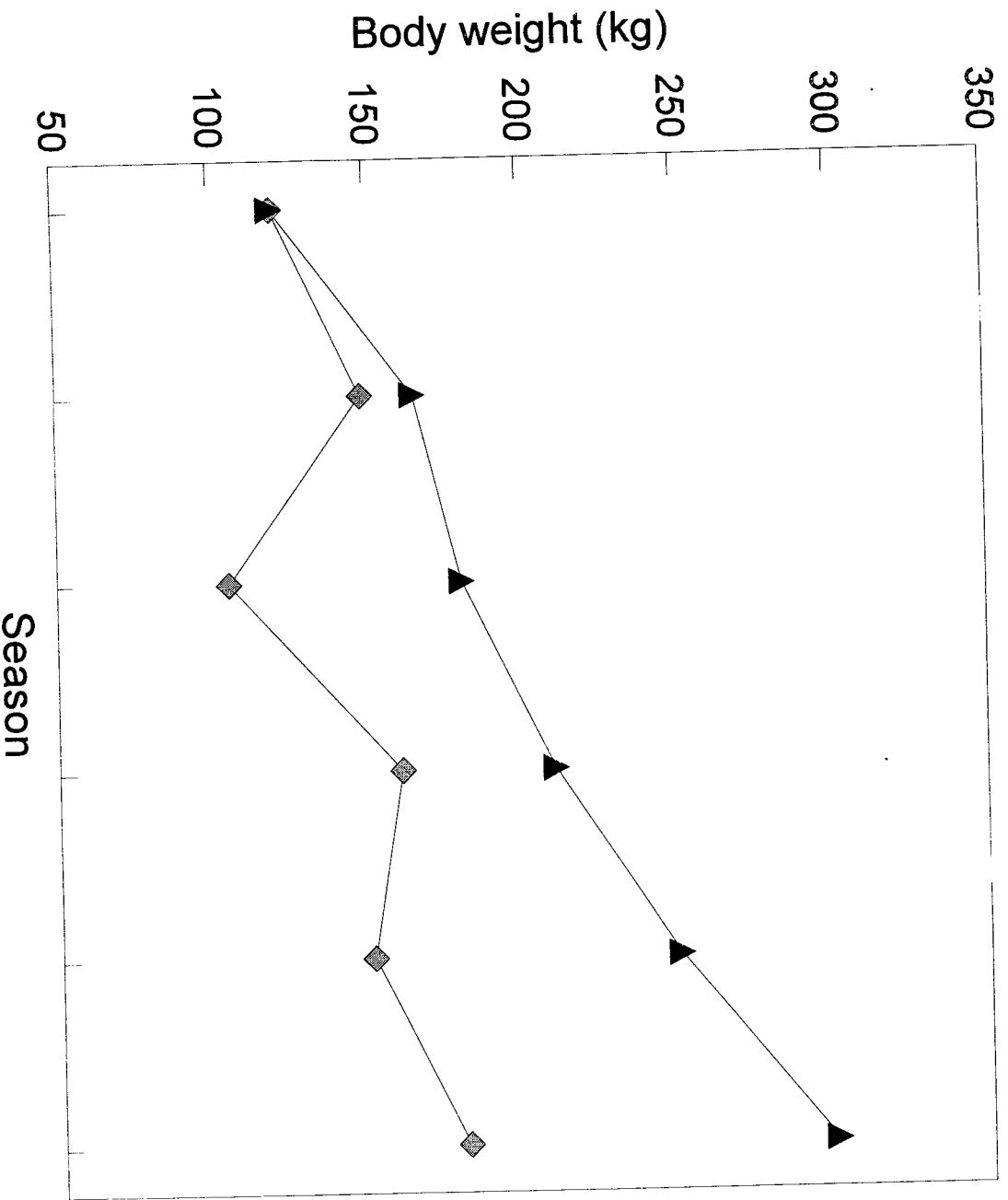
Source : From several authors.



◆ Unsupplemented  
▲ Supplemented

Growth pattern on tropical pastures





◆ Unsupplemented  
▲ Supplemented

# Growth pattern on tropical pastures