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REVIEW ARTICLE

Nutrition: Its role in reproductive functioning of cattle-a review

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Abstract

The relationship between nutrition and reproduction is a topic of increasing importance and concern among dairy producers, veterinarians, feed dealers and extension workers. Nutritional deficiencies cause various reproductive problems. Therefore, the recommendation has been made to feed the cows for top production. Then, the nutrient requirements for reproduction will be adequately met. Animal scientists have made considerable progress during the past years in finding and managing the factors that contribute to the efficient reproduction in domestic animals. Deficiencies of various trace minerals, inadequate vitamin intakes, energy, protein imbalances and excessive protein intakes are mentioned as contributors to infertility and poor reproductive performance. Progress in improving the fertility of domestic animals has been achieved by studying genetic, nutritional, endocrine, disease and managemental factors as they contribute to both fertilization failure and embryo mortality. It has been seen that cessation of estrus with suppression of ovulation or ovulation without estrus result from sub maintenance of feeding. Another important effect of under-nutrition is more number of services per conception which reduces the production level of animal. This paper provides some of the available information regarding relation of nutrition with reproduction of animals.

Keywords: Nutrition, reproduction, fertility, cattle.

Introduction

Livestock production efficiency or productivity is to a large extent dependent on reproductive performance. 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. Differences in nutrition probably account for most variation in reproductive performance between herds and among animals within herds (Holness *et al.,* 1978). Level of feeding (Wiltbank *et al.*, 1962) and bodyweight (Lamond, 1970) also affect the fertility. The effects of nutrition on reproduction in farm animals have been documented by various researchers (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; Mcshane and Keisler, 1991). These reports in general suggest that malnutrition resulting from inadequate, excess or imbalanced nutrients intake may delay puberty, reduce ovulation, lower conception rates, compromise embryonic and fetal survival, result in poor lactation, lengthen post partum anestrus and reduce perinatal survival as well as performance. The effects of nutrition on reproduction are covered extensively here because most animals are poorly fed and improving their feeding can immediately increase their reproductive performance. This review will summarize available evidence on nutrition- reproduction interactions in animals, with an overview of possible mechanisms through which nutritional effects are mediated, and suggest nutritional strategies to improve reproductive efficiency. When studying reproductive problems in dairy herds, nutrition must be considered as there are several causes of infertility but the main factor is nutrition.

Effect of nutrition on puberty, post partum fertility and lactation

Puberty**:** In most reported cases in the literature and in practice, dietary and energy restriction are used to delay the onset of puberty. Weight is apparently the major factor affecting puberty in animals. Thus restricted feeding that slows down growth will increase age at puberty. Poor nutrition delays puberty, reduces conception rate and increases pregnancy losses in heifers (Fleck *et al.*, 1980). Wiltbank *et al.* (1966) referred to a critical age-to-weight ratio which must be reached before heifers attain puberty. According to Topps (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). 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. Oyedipe *et al.* (1982) reported a negative correlation between dietary protein levels and age at puberty. Generally, the onset of puberty occurs when the heifer reaches approximately 40% to 50% of her mature weight (Youngquist and Threlfall, 2007).

Post partum fertility**:** The reproductive performance of the postpartum cow is related to nutritional status (van Niekerk, 1982). Postpartum weight loss, due to underfeeding or high lactation demands, extends the postpartum anestrus period (Entwistle, 1983). Nutrition plays an important part in the initiation of post-partum ovarian activity in all farm species. If animals are poorly fed during this period as often occurs under tropical grazing systems, post-partum infertility, prolonged rebreeding intervals or nutritional anestrus are commonly observed (Smith and Somade, 1994). Cows should be fed well for 22-55 days before parturition and, if possible, for 90 days after parturition (Olivares *et al.,* 1981). McClure (1968) found that cows with a blood glucose concentration of less than 30 mg glucose per 100 ml blood tended to return to service. Cows must, therefore, be on an adequate or rising plane of nutrition and gaining mass during the mating season if conception is to be successful (van Niekerk, 1982).

Lactating Cow**:** During the final 30 days of gestation, lactation is initiated, with production of colostrum and final growth of the fetus. At day 270 of gestation, the uterus and fetus require energy greater than 1600 kcal per day (Bell *et al.,* 1954). Severe anorexia or an imbalance of nutrient intake can predispose the animal to a number of metabolic diseases that constitute the parturition disease complex (Markusfeld, 1993). These diseases are not independent but can increase the risk of subsequent problems. For example, Curtis *et al.* (1983) reported that cows with hypocalcaemia were at increased risk of suffering dystocia, retained fetal membranes, and ketosis. Dystocia and retained fetal membranes are predisposing factors for postparturient uterine diseases. Disrupted intake accompanied by disrupted energy metabolism can result in an increased level of circulating ketone bodies. Miettinen (1990) reported that cows with higher concentrations of circulating ketone bodies had more days to first service, decreased first service conception rates, and more days open. More recently, cows with serum beta-hydroxyl butyrate concentrations of 1100 μmol/L in weeks 1 and 2 of lactation were found to have increased risk of conception failure (Walsh *et al.,* 2004). Removing genetic variation in milk using parent average values as a covariate resulted in a tendency for greater milk from heifers fed the intensive diet (Davis *et al.,* 2011).

Cattle in the tropics are usually dependent on natural pastures and crop byproducts for feed. The crude protein content of the feed is often below 7.5%, which reduces rumen efficiency and reduces the true digestibility of the feed. As a result, lactating cows are unable to meet their nutritional requirements and lose weight and condition during lactation. This prolongs the lactation anestrus period, and cows tend to calve in alternate years (Ward *et al.,* 1971). The percentage change in the cow's body weight during the first 2 weeks after calving is inversely related to the number of days to first ovulation (Butler *et al.,* 1981).

Hormonal changes associated with under-nutrition

Few studies have been made on the relationship between body weight, condition and hormone synthesis or secretion. However, in general the results suggest that poor feeding postpartum reduces luteal function and responsiveness of the ovaries to luteinising hormone (Whisnant *et al.,* 1985).

Effect of nutrients on reproductive efficiency:

The effects of poor nutrition differ, depending on whether the main deficiency is in energy, protein, vitamins, minerals or trace elements. Under traditional management, usually more than one component is deficient (Roberts, 1971).

Energy**:** The most important nutritional factor affecting reproduction in dairy animals is the energy intake of the animal. Energy intake should be in adequate levels, excess intake during late lactation and the dry period can cause "fat cow" problems which lower reproductive efficiency in the next lactation. Inadequate energy intake in heifers will lead to delay in sexual maturity. Cows need energy to maintain milk production as well as to initiate and maintain pregnancy (Youngquist and Threlfall, 2007).

The nutritional challenge of negative energy balance is significant and can adversely affect the reproductive performance of the dairy cow. Negative energy balance is a common finding in high yielders during early lactation because of inadequate consumption of feed to meet the nutrient requirements for high levels of milk production. Energy stores in body tissues are mobilized and weight losses occur. This negative energy balance positively affects the reproductive status of the animal because of the longer interval to first ovulation (Nishany *et al.,* 2013).

To achieve the maximum number of estrous cycles before breeding, cows must ovulate during the early postpartum period (<21 days in milk). Cows fed CE diets during the CU period had a shorter interval between parturition and conception (Cardoso *et al.,* 2013). Research has shown that cows will ovulate approximately 10 days after reaching the lowest point of negative energy balance (Thatcher and Wilcox, 1973). Growth of follicles and ovulation are dependent on the pulsatile secretion of LH (Canfiel and Butler, 1990). In cattle in severe negative energy balance, the secretion of LH is inhibited (Stevenson and Britt, 1979). Disrupted or decreased LH secretion slows the growth and development of the follicle, which delays ovulation (Imakawa *et al.,* 1987). Insulin and insulin-like growth factor-I (IGF-I) are also required for normal follicular growth and ovulation. Cows in negative energy balance have reduced levels of IGF-I. This is an important relationship, given that IGF-I amplifies the effects of LH on the ovary through potentiating the signaling mechanism for LH (Hammond *et al.,* 1991). Therefore, the actions of LH are decreased in cows in negative energy balance because lower IGF-I leads to reduced effectiveness of LH. Consequently, follicles in cows with extremely low IGF-I do not develop normally, and ovulation is delayed because LH is less active. This effect was demonstrated in a study by Thatcher *et al.* (1996). Cows that had first ovulation before 40 days post partum had the highest concentrations of plasma IGF-I.

The other possible effects of deficient energy intake are lower conception rates, longer calving intervals, underdeveloped mammary glands, greater incidence of calving problems and cystic ovaries which are most prevalent in high producing dairy cows that are in negative energy balance common link between this disease and negative energy balance is the abnormal secretion of LH (Cook *et al.,* 1991). Cystic ovaries are associated with increased LH secretion but an inhibition of the preovulatory LH surge. The cumulative effect of these conditions is development of a large cystic follicle that fails to ovulate in the absence of the ovulatory surge of LH. This relationship further strengthens the relationship among energy balance, LH and early postpartum reproductive performance of the dairy cow. Overfeeding often results in weak expression of estrus, subnormal conception rates, high embryonic mortality, decreased mammary gland development and reduced milk production (Patterson *et al.*, 1992).

Protein**:** Although protein is generally regarded as less important than energy for reproduction, low protein intake can also cause infertility. However, it may be difficult to differentiate the effects of low protein intake from concurrent low energy intake, because protein deficiency usually leads to decreased appetite. It has been found that reproductive performance may be impaired if protein is fed in amounts that greatly exceed the cow's requirements. Dietary protein and protein digestion have been categorized by location and rate of digestion of the protein (NRC, 1985). Excessive protein might be harmful in some situations, but not in others.

Dietary crude protein (CP) that is fermented by rumen microflora is defined as rumen-degradable protein (RDP). This protein is degraded to ammonia, single amino acids, and peptides. Ammonia produced in excess of that which the microbial population can utilize is absorbed from the rumen and transported in the circulatory system. A major portion is converted to urea in the liver. Feeding diets high in total CP or diets containing an excess of RDP or soluble CP can predispose lactating cows to elevated blood urea nitrogen (BUN) levels. Butler (1998) completed an extensive review on the effects of protein nutrition on reproductive function and suggested several potential modes of action, including altered uterine environment, altered endocrine profiles, and indirect effects from altered energy partitioning during periods of negative energy balance. According to Ferguson and Chalupa (1989) serum urea nitrogen level of greater than 20 mg/dL resulted in a lower conception rate.

Urea is added to some dairy rations as a source of nitrogen which the rumen bacteria can convert into protein. Elevated blood levels of ammonia or urea or both could alter secretions produced in the reproductive tract itself and affect viability of the ova, sperm or embryo. In addition, the hormonal balance required for normal function also may be involved (Buttler, 1998). Williams *et al.* (1987) also found that high-protein diets increased the urea nitrogen content of uterine secretions but found no differences in fertility or *in vitro* embryo development. Jordan *et al.* (1983) found that high crude protein (CP) diets changed the concentrations of magnesium, potassium, phosphorus and zinc in uterine secretions. Overall, high protein diets increase the nitrogen content of uterine secretions, in addition to shifting mineral composition; however, a direct effect of these changes *in utero* on fertility and embryo viability is less clear. Blanchard *et al.* (1990) evaluated the effects of a high Rumen Degradable Protein (RDP) diet on fertilization and embryo quality. Cows fed high RDP diets had similar numbers of fertilized, unfertilized, transferable and nontransferable ova compared with cows fed low RDP diets. Elrod and Butler (1993) proposed that the products of excessive protein degradation in the rumen decreased uterine pH, which may reduce fertility. Garcia-Bojalil *et al.* (1994) however, reported no difference in ovarian follicle development or number and quality of recovered embryos due to protein level (12.3% versus 27.4% CP). These data suggest that some other mechanisms may be involved for reduced fertility.

Altered hormonal balance caused by elevated BUN levels also may decrease fertility and reproductive. Excessive ammonia or chronically elevated ammonia may alter hormonal status and thus performance of the animal. The metabolic signals have not been established, but intermediates of the urea cycle such as arginine may potentially cause shifts in insulin and alter glucose metabolism. Fernandez *et al.* (1988) showed that subclinical ammonia toxicity decreased insulin concentrations in the plasma of steers.

Two studies (Jordan and Swanson, 1979; Blawviekel *et al.,* 1986) showed that the amplitude of the LH peak was higher for cows fed high-protein diets. Progesterone was more variable, with one study showing lower progesterone (Jordan and Swanson, 1979) and the other showing no differences (Blawviekel *et al.,* 1986). These studies did not establish an endocrine mechanism through which high CP diets might alter reproduction.

***Fat*:** Inadequate dietary energy intake and poor body condition can negatively affect reproductive function. Supplemental lipids have been used to increase the energy density of the diet and avoid negative associative effects often experienced with cereal grains. Supplemental lipids may also have direct positive effects on reproduction in beef cattle independent of the energy contribution. Supplemental Poly Unsaturated Fatty Acids (PUFA) has been shown to increase progesterone (P_4) concentrations by enhancing development of luteal cells, reducing uterine synthesis of prostaglandin (PGF2α), delaying luteolysis, and directly alleviating hepatic steroid metabolism. Additionally, supplemental PUFA may also increase circulating insulin concentrations, which in turn has also been shown to reduce hepatic expression of P_4 catabolic enzymes. Feeding fat increases follicle numbers and the size of the dominant follicle. PUFA supplementation may increase reproductive performance directly by improving uterine environment and embryo development, perhaps by increasing circulating concentrations of P_4 (Lopes *et al.,* 2009).

***Minerals*:** It is clear that adequate amounts of minerals must be provided, but little is known about the effects of marginal deficiencies and imbalances. The same is true of excessive intakes of minerals which may indeed be harmful (Smith and Chase, 1980). The effect of various minerals has been listed out here:

Calcium: Calcium deficiency will lead to poor reproduction of the animal. Calcium, the relationship of calcium to phosphorus, and the balance of calcium with vitamin D also have been linked to altered reproductive performance. Ward *et al.* (1971) reported that cows fed high calcium and high vitamin D diets ante partum had more rapid uterine involution, fewer days to first service, and fewer days open. As per Hignett and Hignett (1953) a minimum calcium-to-phosphorus ratio of 1.5:1 and 2.5:1 for lactating cows with a minimum daily phosphorus intake of 30 g is suitable for normal reproductive functioning.

Parturient hypocalcaemia significantly increased the odds ratio for dystocia and retained placenta. These investigators concluded that the loss of muscle tone associated with hypocalcaemia could reduce normal uterine function. Early research found that feeding low calcium diets prevented parturient paresis (Goings *et al.,* 1974).

***Phosphorus**:* The deficiency of this mineral result in poor reproductive performance due to inactive ovaries, delayed sexual maturity and low conception rates (Smith and Chase, 1980). Morrow (1969) reported that dairy heifers suffering from phosphorus deficiency had high rates of infertility as measured by services per conception. Increasing phosphorus in the diet returned blood levels to normal, with improved fertility.

Trace minerals:

Selenium: The source of selenium deficiency is the soil deficient in selenium. Selenium deficiency in dry cows has been reported to cause abortions, a high incidence of embryonic fetal loss, poor fertility, increased incidence of metritis, a higher level of general infection and the birth of dead or weak calves retained placenta (Smith and Chase, 1980). Diets should contain at least 0.1 ppm selenium on a dry matter basis. In herds where selenium levels are extremely low, injections are often required to rapidly return blood selenium levels to normal. After injection, feed supplements may provide enough selenium to maintain adequate blood levels in the cow. Blood tests are recommended to confirm selenium status when questions arise.

Iodine: Inadequate thyroid function reduces conception rate and ovarian activity. Thus, iodine deficiency impairs reproduction and iodine supplementation has been recommended when necessary to insure that cows consume 15-20 mg of iodine each day. However excess iodine resulted in abortion and decreased resistance to infection and disease (Smith and Chase, 1980).

Potassium: Limited research suggests that feeding high levels of potassium may delay the onset of puberty, delay ovulation, impair corpus luteum (yellow body) development and increase the incidence of anestrus in heifers (Smith and Chase, 1980).

Other Minerals:

Copper, manganese, and cobalt deficiencies have been associated with impaired ovarian function, silent estrus and abortions. Fluoride toxicity lowers fertility (Smith and Chase, 1980). Zinc deficiency increased the length of labor and bleeding time in the rat. This relationship also has been reported for the ewe (Youngquist and Threlfall, 2007).

Copper: Copper deficiency signs are decline in fertility, inactive ovaries and high incidence of Retention of Placenta (ROP). Daily requirement of Copper is 10 ppm (Petersen, 1984). Copper (Cu) availability is also strongly affected by other minerals, in areas where Sulfur or Molybdenum is high, Cu supplementation should be increased (Petersen, 1984).

Cobalt: Cobalt is required for the microbial synthesis of Vit-B_{12}. Deficiency signs are unthriftiness and anemia as well as delayed uterine involution, irregular estrus cycles and decreased conception rate. Dietary requirement of Cobalt for lactating cows is 0.1 ppm of Dry Matter Intake (MDI) (Petersen, 1984).

Manganese: Manganese is required for activation of many enzyme systems and also involved in luteal tissue metabolism. Deficiency symptoms are delayed return to estrus postpartum, reduced conception rate and delayed ovulation. Abortions and small birth weights also reported due to inadequate Manganese intake. Dietary requirement is 40 ppm of ration on Dry Matter Basis (DMB) (Petersen, 1984).

Zinc: Zinc is recognized as an essential nutrient required for normal growth. Zinc has been identified as a cofactor for more than 200 proteins and enzymes. Zinc's role in metabolism, growth and repair of normal epithelial tissue, the role in reproduction is not fully understood. Zinc deficiency signs are delayed testicular development in young bull and testicular atrophy in the adult. Also atrophy of seminiferous tubules and cessation of spermatogenesis. Lower conception rates have been reported in cows. Dietary requirement is 40 ppm of ration on DMB. This is adequate for normal testicular function. Feeding trace mineral salt should be providing adequate amounts of Cu, Co, Mn and Zn for normal reproduction (Chiba, 2009).

Vitamins:

Proper vitamin and mineral balance must be provided in dry cow rations when feed intake is restricted and (or) low quality forage is fed to control or reduce body condition. To ensure adequate intake, vitamins and minerals should be fed in small amounts of low energy concentrates or mixed in a complete dry cow ration (Smith and Chase, 1980). Most commercial concentrates contain supplemental vitamins so the probability of infertility due to a vitamin deficiency is greatly reduced.

Vitamin A: Vitamin A maintains the tissue integrity of reproductive tract. Its deficiency will lead to delayed sexual maturity, abortion, the birth of dead or weak calves, retained placenta and metritis. The recommended daily supplementation for dairy cows is 30,000-50,000 units. Beta-carotene (carotene) also has been investigated as a nutrient having special requirements for reproduction. Hemken and Bremel (1982) reviewed this topic in 1982 and concluded that adequate evidence did not exist to support the establishment of a requirement for carotene above that for vitamin A. Chew *et al.* (1984) reported high levels of carotene in the blood, corpus luteum and follicular fluid, but effects on ovarian functions were not described.

Dairy cows and heifers consuming diets deficient in β-carotene suffered with following problems like delayed uterine involution, delayed first estrus after calving, delayed ovulation, increased incidence of cystic ovaries, more early embryonic death and abortion. β -carotene supplementation at 300 mg/cow/day reportedly restored reproductive function to normal, but Vitamin A was not effective (Smith and Chase, 1980).

Vitamin D: This vitamin is required for normal calcium and phosphorus metabolism. Its requirement in dairy cattle 150 IU/lb of ration DM or 6000 to 12000 IU/cow. Deficiency may result in delayed onset of estrus and ovarian inactivity. In high Ca intake uterine involution was more rapid with Vit D supplementation; however, with moderate Ca intake (100gm), Vit D appeared to delay uterine involution. (Zinser and Welsh, 2004)

Vitamin E: Along with Selenium it functions as an antioxidant and is important in the prevention of white muscle disease in calves. Recently 1000 IU of supplemental Vit E during the last 40 days of gestation significantly reduced the incidence of Retention of Fetal Membranes (RFM) in dairy cows fed diets containing greater than 0.12 PPM Se. Daily requirement of Vit. E is 15 IU/kg of feed.

Discussion

Form the present findings it is clear that poor nutrition can result from inadequate nutrient density in the diet, inadequate amounts of the diet fed and insufficient access to the diet. Deficient and excess nutrient supply could be equally detrimental. Even nutritional treatments that result in highly desirable responses for one reproductive state may become counterproductive in a subsequent phase or for the reproductive economy of the animal as a whole (Robinson, 1990). The common theme underlying the process is a link between nutritional and metabolic inputs that support complex interactions between the gonadotropic and somatotropic axes. Multiple hormonal and metabolic signals from the liver, pancreas, muscle, and adipose tissues act on brain centers regulating feed intake, energy balance, and metabolism. Among these signals, glucose, fatty acids, insulin-like growth factor-I, insulin, growth hormone, ghrelin, leptin, and perhaps myostatin appear to play key roles. Many of these factors are affected by changes in the somatotropic axis that are a consequence of, or are needed to support, high milk production. Ovarian tissues also respond directly to metabolic inputs, with consequences for folliculogenesis, steroidogenesis, and the development of the oocyte and embryo (Chagas *et al.,* 2007).

The nutritional status of animals is difficult to measure, and this complicates interpretation of nutrition and reproduction interactions (Haresign, 1984). An animal's nutritional status is usually assessed on changes in its live weight and body condition. However, these are long-term changes while many of the events of reproduction *e.g.,* ovulation, fertilization and placentation take only a short time.

Reproduction is controlled by complex neuro-hormonal mechanisms built around the hypopyseal-pituitary-gonadal axis. Gonadotrophin Releasing Hormone (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 centers, to complete the neurohypophyseal- pituitary-gonadal axis. Thus in the post-partum period, a rapid decrease in estradiol after parturition removes the negative feedback 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 (Smith and Somade, 1994). 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 ovariectomized adult ewes the pulsatile release of LH during anestrus ceased when the ewes became emaciated, suggesting that the effect was mediated at the higher centers through mechanisms not involving the gonads. Reviewing the work of Day *et al.* (1986), who examined the effects of restricted energy intake in prepubertal heifers, Short and Adams, (1988) concluded that the evidence suggested that restricted energy prevents or slows the maturational process at the pituitary-hypothalamus level.

The best recommendation at present is to provide a feeding program for dairy cows which is balanced for all nutrients and meets all known nutrient requirements. This approach must be used on a long term, continuing basis in the herd if it is to be successful. Nutrition of the pregnant cow, both while lactating and dry, should also consider aspects of placental and fetal development that may affect health and performance of the progeny (Bach, 2012). The same approach must be used for replacement animals and dry cows as well as milking cows since some of the reproductive problems related to nutrition may develop over a long time. Likewise, when nutritional problems are corrected.

Postpartum energy intake above maintenance can increase reproductive success in thin cows. Thus, the management decisions of when to place the bull with the cows and when to wean the calves are critical and should match the available nutrient supplies to the demands of the cows.

So it can be said that inadequate nutrition delays puberty and sexual maturity in heifers and resumption of ovarian activity and estrus in postpartum cows. If a cow is underfed when pregnant it will be in poor condition at calving and will be slow to resume cycling and reconceive. Ideally, the cow's body condition should improve gradually through pregnancy, but excessive fatness should be avoided. Cows will probably lose weight after calving, but weight loss should be minimized through good feeding to allow them to start cycling again as soon as possible.

In conclusion, feeding and managing a herd of high producing dairy cattle while maintaining a high reproduction rate is a tremendous challenge. New knowledge of the relationships between nutrition and reproduction is being discovered yearly. Until such new dramatic breakthroughs are discovered, nutritionists and veterinarians will have to continue to strive to ensure that producers are applying daily all the currently known facts about nutrition, herd health and reproduction. Good managers can expect to achieve good reproductive performance on a herd basis if they are diligent in assuring that animals are fed properly, kept free of disease and pay attention to the details of herd management including excellent heat detection and proper insemination techniques. Proper nutrition is but one part of a successful reproduction program. Good nutrition is vital but absence of any one of the other key components likewise will result in a poor herd reproduction program.

Implications for management

Research has established that the nutritional status of the animal alters the reproductive function of the animal. In fact, the current question is how and to what level nutrition alters the reproductive function of the high producing dairy cow. Poor nutrition can result from inadequate nutrient density in the diet, inadequate amounts of the diet fed and insufficient access to the diet. Prepartum metabolic disorders have a carryover effect that can impede reproductive function because of the residual effects of severe negative energy balance. This phenomenon emphasizes the importance of nutritional management, as well as overall management of the herd. This aspect of farm management will become increasingly critical as the genetic base of the dairy cow population continues to improve. As noted by Norman and Powell, (1992) tremendous potential exists in the current gene pool of dairy cattle. The long range challenge will be maximization of this genetic potential to its fullest extent.

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