Nutrition and Reproduction in Dairy Cattle

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Introduction

Nutrition and reproduction are two of the cornerstones of successful dairy production and profitability, and nutrition has an important impact on reproductive performance. The industry as a whole has done a remarkable job of breeding better cows, improving housing management to mitigate environmental stresses, increasing forage availability and digestibility and improving overall nutritional management to support higher levels of milk production. Meanwhile, numerous individuals have correlated the dramatic rise in milk production per cow with the apparent decline in reproductive performance and have suggested that the two are linked. While there are some issues of high milk production that can negatively impact reproduction, one must be cautious about drawing any cause and effect conclusions about the associations observed. Using outcomes such as increased days open and more prolonged calving intervals would suggest that reproductive performance has decreased in recent years but this conclusion is problematic. One issue that will definitely cloud the picture is the increasing length of lactation possible with today's higher producing cows and the improved record keeping options available now. Higher producing cows remain in the herd longer and receive more insemination attempts than previously, while low producing cows tend to become pregnant or are at risk of being culled from the herd at an earlier point in lactation. Recent work presented by LeBlanc at the 2009 ADSA meeting using Canadian data revealed that at the individual cow level, there were small conflicting effects of level of milk production on time to pregnancy.[1] At the herd level, higher producing herds had significantly higher pregnancy rates suggesting that management efforts to provide for high milk production can also be compatible with good reproductive performance.

Genetic selection efforts in dairy cattle breeding programs have placed an emphasis on increased milk yield and these higher producing cattle are at an increased risk for experiencing nutrient shortages, especially in early lactation. Metabolic demands for milk production often lead to negative energy balance (NEB) which impairs reproductive performance by impairing resumption of cyclicity; depressing oocyte, corpus luteum, and embryo quality; and negatively impacting the maintenance of pregnancy. Nutritional management efforts to mitigate the impact of milk production issues on reproduction typically center on maintaining or increasing dry matter intake (DMI), manipulating carbohydrate fractions, maintaining adequate effective fiber, feeding supplemental fats, avoiding excessive or inappropriate protein, optimizing mineral and vitamin levels and minimizing the risk of known toxins such as gossypol.

Nutrition and Periparturient Interactions

Much of our success or failure in terms of early lactation milk production is the result of how well cows were managed during the periparturient period and much work has focused on the proper feeding management of these cows to minimize the risk of metabolic issues. However, it appears that much of the previous advice that has been given regarding maximizing feed intake and increasing energy density immediately prior to calving has not been supported by recent research. Despite large declines in DMI[2,3] that may range from 30-45% depending on body condition score, diet type, season, stocking density and other management issues such as regrouping, most cows do not experience significant NEB immediately prior to calving. A common statement that was formerly used by many consultants, "we need to maximize DMI prior to calving", appears to be incorrect. A more correct approach may be that we need to minimize the drop in intake that occurs during the final 7-10 days prior to calving. Work in this area has been somewhat inconsistent, but the pattern that appears to be emerging is that restriction of total energy intake throughout the dry period appears promising in terms of effects on NEFA's, BHBA's, liver triglycerides and early lactation performance.[4-7] Overfeeding energy does not appear to be beneficial and decreasing energy density of dry cow diets to near NRC recommendations (~ 0.57-0.6 Mcal NE_L/lb) may help to decrease health problems (and presumably, improve reproductive performance later). Cows allowed free access to moderate energy diets in experiements by Drackley et al., appear to have higher insulin concentrations in the face of similar glucose concentrations (i.e., insulin resistance).[7]

One management approach that has garnered widespread support in the dairy community is the use of DCAD diets (diets formulated to provide a negative dietary cation – anion difference of approximately -10 meq/ 100 g ration DM).[8,9] As a consequence of the implementation of DCAD diets, the negative impact of both clinical and subclinical hypocalcemia has been markedly reduced in most herds that have successfully adopted this feeding approach to prepartum cows. Briefly, feedstuffs are selected that will provide the lowest levels of potassium that are reasonably possible, trying to achieve levels near 1.5%. Calcium is added to about 1-1.2%. Next, Mg, P and S are typically added to levels of about 0.4% and then chloride salts are added to achieve the desired DCAD. As a general rule, Cl is added at a level approximately 0.5% less than the ration's K level, assuming the other minerals have been balanced properly. As a word of caution, Cl (and the other anionic minerals) are not very palatable and efforts should be made to keep the supplementation level of Cl to 1-1.2% or less, hence the need to reduce the source of K as much as possible. One risk of feeding DCAD diets is the palatability issue. However, as mentioned previously, if the intake is somewhat depressed but maintained at an adequate level throughout the prepartum period, cow performance will usually be good. Achieving an adequate calcium level at calving and during the immediate postparturient period is the goal of DCAD diets. The benefit of normocalcemia is proper function of smooth muscle (GI tract for improved DMI and uterine tissues for normal contractility, healing and involution).

Another interesting finding related to hypocalcemia is its relationship to immune function. Kimura et al. reported an association between intracellular Ca stores and peripheral blood mononuclear cell and neutrophil function.[10] In this work, the authors demonstrated that extracellular calcium status in preparturient dairy cattle affected intracellular Ca flux in these cells that are critical to proper immune function. Therefore, at least part of the periparturient immunosuppression observed in dairy cows may in fact be due to the decreased function of peripheral blood mononuclear cells as a consequence of the blunted Ca signaling. Consequently, maintaining normocalcemia and DMI during the preparturient period may help improve immune function at the cellular level as well as reducing the risk of retained placenta and metritis-endometritis complex, leading to improved health, milk production and reproductive performance.

A major risk factor for metritis, retained placenta (RP) or both is a compromised immune function. While the specific cause for immunosuppression is unclear, a variety of nutrition-related issues such as the preparturient drop in DMI, poor vitamin and mineral status, hypocalcemia, excessive mobilization of body fat and protein all contribute.[11-14] Cows that go on to develop RP and metritis have been shown to be more likely to have had elevated NEFA's, reduced DMI and compromised neutrophil function prior to calving.[13] Based on a variety of studies, cows calving with RP are usually 4-6 times more likely to develop metritis and many of these cows also go on to develop clinical or subclinical endometritis at a later date. The median lactation incidence risk for RP and metritis has been shown to be 8.6% and 10.1% respectively[15], although in the author's experience, typical metritis risks are much higher in most herds. Metritis is highly associated with reduced fertility. Lee et al., demonstrated that cows affected by metritis had a 30% reduction in conception risk and an increase in median days open of 13-15 days.[16] Since RP, metritis and endometritis are largely diseases of compromised immune function, management efforts should be directed towards maintaining adequate feed intake during the periparturient period and maintaining the proper levels of two key nutrients related to immune function – selenium and vitamin E.[17] Selenium should be added to diets at the legal upper limit of 0.3 ppm Se and in the author's opinion, vitamin E should be targeted for a level of approximately 2000 IU/cow/ day.

The postparturient period in dairy cattle is a time of rapidly increasing energy demands from milk production and a slowly increasing, but lagging, feed intake. Energy balance (EB), defined as the difference between dietary intake of utilizable energy and the energy expended for body maintenance and milk production, goes negative due to the discrepancy between energy input and output.[18] Bauman and Currie have described the issues of homeorhesis and homeostasis as they relate to nutrient prioritization in dairy cattle with priority being given first to milk production (i.e., feeding the young calf that would normally be at her side) rather than reproduction (producing the next generation).[19] In lactating dairy cows, homeorhetic mechanisms coordinate nutrient partitioning towards milk production, even to the point of mobilization of significant stores of body fat and protein to meet these demands resulting in more nutrients being utilized than can be consumed resulting in NEB. This NEB is usually at its most negative point (energy balance nadir) during the first 1-2 weeks after calving in normal cows but may occur much later in cows that suffer periparturient disease issues or additional stressors such as overcrowding pre or post-calving. After this NEB nadir, energy intake increases as feed intake rises, eventually resulting in positive energy balance. For most normal dairy cows, positive energy balance should be reached by 45-60 days in milk, but may be delayed until 10-12 weeks or beyond.[20] However, due to the poor sensitivity of body condition scoring, producers or consultants may not recognize a positive change in body condition until 120 days in milk or later.

The resumption of cyclicity is dependent upon the resumption of the normal pulsatility of luteinizing hormone (LH) release. Follicle stimulating hormone (FSH) pulses actually resume within the first 2-7 days in most cows. Cyclicity (first postpartum ovulation) typically resumes before positive energy balance is reached, but after the NEB nadir. Canfield and Butler showed time to first ovulation to be a function of days to NEB nadir (1^{st} Ovulation = 10.4 + 1.2*Days to nadir, $r^2 = 0.77$).[21,22] In their work, nadir occurred at approximately 14 days in milk for lactating cows, thus putting first ovulation at about 27 days.

Much attention has been placed on finding a direct signal or link between energy balance and the resumption of LH activity. During periods of negative energy balance, cows will catabolize fat stores to meet her energy demands, but this utilization of fat does not yield a net increase in glucose. The mobilization of fat leads to increased blood levels of non-esterified fatty acids (NEFA). Elevated levels of NEFA and depressed levels of glucose can have direct effects on oocyte and embryonic quality, but the compound with the greatest evidence of having a direct effect on LH secretion is insulin-like growth factor-1(IGF-1). IGF-1 receptors have been found in the hypothalamus and the anterior lobe of the pituitary and there is a positive association between IGF-1 and LH pulse frequency, indicating that IGF-1 may act as a mediator of ovarian recovery.[23]

Impact of NEB on Reproductive Performance and Management:

Negative energy balance in early lactation is the largest contributor to nutritionally-related reproductive challenges in the dairy cow. Lopez-Gatius et al., demonstrated a large, negative effect of early lactation NEB, as evaluated by changes in body condition score, on first service conception risk and number of days open.[24] Cows experiencing more than 1 body condition score (BCS) loss had a 10% reduction in first service conception risk and accumulated an average of 11 more days open as compared to cows losing less than 0.5 BCS. Others have demonstrated that cows losing > 1 BCS had a first service conception risk of 17% as compared to 53% for cows only losing 0.5 to 1 BCS from calving to first service.[25]

More recent work by Walsh et al., also illustrates the impact that NEB and the resulting postpartum anovulatory condition has on reproductive performance.[26] Their work utilized approximately 1300 cows located in 18 herds and classified cows as anovular if progesterone levels from skim milk samples taken 14 days apart at 46 and 60 days in milk were less than 1.0 ng/ ml. Anovular cows inseminated using timed AI were 55% less likely to conceive to first insemination and had a median days open of 156 vs 126 for cycling cows.

Energy balance issues can exert their negative effect on reproductive efficiency through several different ways. One way is through impaired GnRH secretion from the hypothalamus which leads to inadequate LH release from the anterior pituitary. There is evidence that LH pulse frequency may be adjusted or regulated by serum insulin and IGF-1 concentrations. These compounds usually reflect a cow's nutrient status, rising as dry matter intake increases during the postpartum period.[27]

As a consequence, there can be a couple of scenarios for the cow that is emerging from the effects of NEB. In scenario one, there is inadequate LH pulsatile secretion to continue follicular growth. Small follicles emerge with a new follicular wave since FSH levels are usually not a problem. Due to the inadequate LH support, however, small follicles are not able to continue growing and instead, undergo atresia within days of the start of a follicular wave. With the aid of ultrasound, in cows with inadequate LH support, one will see small "static" ovaries with very little follicular activity or alternatively, multiple small follicles less than 8 mm in diameter.[28]

In the second scenario, there is partial recovery of the hypothalamus/ GnRH with adequate pulsatile release of LH, but failure to achieve a surge release. As a consequence, one might find large follicles (10-25 mm in diameter or greater) and/ or follicular cysts (follicular structure $\geq$ 25 mm present and persistent for 10 days or more, but in the absence of a CL).[29] In either case, there is inadequate or unhealthy growth and poor quality follicles.

Estrogenic function is also compromised in anestrus anovulatory cows. Cows with small follicles that turn over rapidly should never truly display signs of estrus and cows with large follicles or follicular cyst would have estrogenic potential but probably would not express estrus due to the absence of progesterone priming of the behavioral centers of the brain. If these follicles are forced to ovulate via exogenous administration of GnRH, fertility is depressed at that insemination.

Negative energy balance can also affect oocyte quality and developmental competence of early embryos. Cows in NEB have varying levels of clinical or subclinical ketosis and the presence of β-hydroxybutyrate (BHBA), or perhaps, more importantly, the reduced levels of glucose, may have direct effects on early embryonic development following fertilization. Follicles growing under conditions similar to subclinical and clinical ketosis (low glucose but elevated BHBA) have impaired early embryonic development including blocked cumulus expansion and a reduced blastocyst rate.[30] Additional work showed a negative effect of NEB, non-esterified fatty acids (NEFA), and BHBA on follicular steroidogenesis of granulosa cells.[31,32] Granulosa cells become large luteal cells after ovulation and luteinization, and together with theca (small luteal cells), are the cells in the corpus luteum that produce progesterone. If steroidogenesis is impaired, future production of progesterone is likely to be depressed, resulting in impaired fertility, ie., lower follicular quality, less intensive signs of estrus, decreased probability of fertilization, and increased risk of embryonic loss.

An entirely separate pathway for impaired fertility due to NEB relates to the systemic effects on the liver and overall immune function. Cows that must mobilize excessive amounts of protein and adipose tissue undoubtedly experience ketosis, impaired liver function and impaired neutrophil function. Cows are designed to conserve glucose and to utilize ketones, but in somewhat limited amounts. If excessive triglycerides are broken down in response to energy demands, NEFA levels in the circulation increase. Once in circulation, NEFA's have 3 major potential fates: 1) they can be utilized by the mammary gland for milk fat synthesis, 2) they can be used by tissues as an energy source (but with no net production of glucose), or 3) they can be re-esterified by the liver into triglycerides. Once in the liver, these fats can be incorporated into very low density lipoproteins for export out or they can accumulate in the liver due to failed or slow export. Unfortunately for cows, fat accumulation in the liver is a very common sequela due to a limited capacity to produce apoprotein B, a compound necessary for exportation of fats. Negative protein balance combines with NEB to impair immune function. Severe or prolonged energy deficiency can lead to an accumulation of ketoacids in the blood, impairing lymphocyte, neutrophil, and macrophage function. The result is an overwhelmed, fatty liver with impaired function and an increased risk of metritis, endometritis, and reduced fertility.

Fat Feeding and Reproductive Performance

Fat feeding during the periparturient period in an attempt to improve reproductive performance is a complex and controversial topic. On one hand, feeding excessive levels of fats has been shown to depress DMI. [33] The author suggested that the depression in feed intake could occur via a variety of potential means such as action on the brain satiety center, reduction in ruminal fermentation and gut motility, decreased acceptability of diets by cattle, feedback of gut hormones such as cholecystokinin, or by feedback of oxidative endproducts from the liver. However, most diets commonly fed to dairy cattle do not contain total fatty acid levels above 5.5 to 6% as was common in data set reviewed by Allen and current suggestions regarding the supplementation of fat, especially at levels above 5%, typically involve the use of multiple sources of fat (i.e., common feed ingredients and oilseeds + added animal fat + calcium salts of fatty acids) since the negative impact of fat feeding appears greater with free unsaturated fatty acid sources.

On the other hand, there are some overall positive effects of fat feeding, especially targeted fatty acid sources. Based on reviews by Staples et al.[34], and Jenkins and Overton[35], the addition of polyunsaturated fatty acids may be beneficial at improving fertility by a variety of potential routes:

- Increased production of prostaglandin $F_{2\alpha}$ (omega-6 fatty acids such as linoleic acid)
    - Linoleic acid, an omega-6 fatty acid, is converted to arachidonic acid by body tissues. Arachidonic acid is a key inflammatory intermediate that is critical to immune and inflammatory responses. One key effect of increasing arachidonic acid is the increase in proinflammatory agents such as cytokines, interlukins, and prostaglandin $F_{2\alpha}$. These agents facilitate a more rapid healing and involution of the uterus following calving partially by improving the function of certain white blood cells. Enhancing the production of these agents from calving through the first 40-60 DIM should help cattle fight infections and lead to improved uterine health and improved fertility. Work out of Florida compared Ca-salts of safflower oil (64% linoleic acid) with Ca-salts of palm oil (47% palmitic acid, a saturated fat) that were fed from ~ 30 days prepartum until ~ 30 DIM.[36] Cows fed the Ca-salts of safflower oil (omega-6 fatty acid) demonstrated improved neutrophil function and better overall immune health.

- Inhibition of prostaglandin $F_{2\alpha}$ production by reducing the production of arachidonic acid (omega-3 fatty acids such as linolenic acid, eicosapentanaenoic acid (EPA), and docosahexaemoic acid (DHA))
    - Once breeding has started, one positive and desirable outcome would be to at least partially suppress some of the prostaglandin $F_{2\alpha}$ produced, thus potentially prolonging embryonic life. In order to successfully maintain a pregnancy, an embryo must produce adequate amounts of interferon-tau to block the normal luteolytic cascade that usually occurs around days 15-17 post-breeding. Omega-3 fatty acids have been shown to reduce the uterine release of prostaglandin $F_{2\alpha}$ during early pregnancy in dairy cattle.[37] Reducing the secretion of prostaglandin $F_{2\alpha}$ by supplementation of diets with

specific omega-3 fatty acids may work in concert with interferon-tau to increase embryo survival and hence to improve reproductive performance.[38]

- Larger Follicles and Greater Progesterone
  - Prior to ovulation, the dominant follicle grows from a tiny antral follicle to a large (15-20 mm diameter) follicle over a period of 7-10 days. Once ovulation has occurred, the old follicle is quickly converted into a new structure called a corpus luteum which is critical in that it produces progesterone. Progesterone is vitally important in that it prepares the uterus to receive the early embryo and maintains the pregnancy. There is a positive association between the rate of rise of progesterone during the first 7-10 days following ovulation and breeding and the subsequent likelihood of producing and maintaining a pregnancy. Larger, healthier follicles tend to produce larger and healthier corpora lutea and presumably, higher levels of progesterone. Previous work has shown that feeding fat to dairy cattle is associated with larger dominant follicles[27,39] and in some studies, the feeding of omega-6 (linoleic) or omega-3 (linolenic) fats was associated with larger dominant follicles as compared to fats rich in oleic acid.[40]

- Enhancement of energy balance during periparturient period (reduction in duration and severity of NEB and anestrus/ anovulatory period)
  - By providing additional energy in the form of fat, cows may experience a less severe NEB challenge, and thus initiate cyclicity sooner. Fertility is enhanced if cows cycle 2-3 times prior to attempting insemination. This benefit should result only if the addition of fat reduces the supply of NEFA by reducing fat mobilization. However, this effect is likely present only if the fat feeding adds additional caloric support without decreasing the efficiency of digestion of the remaining feedstuffs such as structural and non-structural carbohydrates. If overall digestive efficiency is depressed by the addition of fat, the energy benefit of extra lipid in the diet may be negated. Alternatively, provision of additional fat may actually increase the level of circulating lipids. A review by Drackely suggested that dietary fat does not suppress lipid mobilization and if fact, demonstrated an increase in NEFA concentration as fatty acid intake increased in lactating cows.[41]

Protein Nutrition and Reproduction

Dietary protein and the relative levels of rumen degradable protein (RDP) have been associated with fertility challenges in dairy cattle.[42] Often, but not consistent across all studies, an elevated crude protein and more specifically, elevated RDP has been linked to reduced fertility, especially in high producing cattle[43]. During normal digestion of feedstuffs, RDP is broken down into ammonia that can be utilized by rumen microbes for microbial protein synthesis. Excessive levels of RDP or inadequate levels of fermentable carbohydrates can lead to excessive ammonia that diffuses through the rumen and enters the portal circulation where it is detoxified by the liver via conversion to urea. Some of this urea is recycled via saliva into the rumen but most is excreted by the kidneys as waste. Prior to being excreted by the kidneys, urea circulates through the blood and tends to equilibrate in a variety of tissues, including the uterus.

An excessive level of urea has the potential to impact reproduction negatively in several ways. One avenue for reduced reproductive performance is by impacting energy balance, especially in the postpartum cow. The liver utilizes energy in its effort to detoxify ammonia that escapes from the rumen. Feeding excessive RDP during the postparturient period may exasperate the negative energy balance already occurring and further delay the resumption of cyclicity. While some nutritionists like to aggressively feed protein during the postparturient period to provide additional amino acid precursors for gluconeogenesis and tissue repair, providing a larger portion as rumen escape protein and restricting the duration of the higher feeding levels to the first 7-10 days in milk is likely prudent.

In general, most of the work examining the impact of CP on fertility has suggested that concentrations of blood urea nitrogen above 19 mg/dl are more commonly associated with impaired fertility.[43] The mechanism for decline in fertility is thought to be due to increased urea concentration in oviductal, uterine and vaginal fluids; modified concentrations of magnesium, potassium, phosphorus, or zinc in uterine secretions; or perhaps due to changes in uterine pH.[44] However, there is also considerable work demonstrating little or no effect of urea nitrogen on fertility.[45-47]

Work by McCormick et al., in grazing cattle illustrated the impact of differing levels of crude protein (CP) and proportions of RDP and rumen undegradable protein (RUP) during early lactation[48]. In this study, cattle fed excessive CP (23.1%) but limited RUP (25% of CP) had lower first service conception risks (24 vs. 41%) and a lower cumulative proportion pregnant (53 vs 75%) than cows fed a moderate CP (17.7%) and limited RUP (28% of CP) or moderate CP (17.2%) and high RUP (40% of CP).

In the aforementioned study, the crude protein supplement was soybean meal and this appears to be the most common supplement used in many of the trials examining the impact of excessive CP on fertility. However, a word of caution is due here. Increasing crude protein by increasing soybean meal has the potential to also increase the risk of phytoestrogens in the diet, which may result in disruption in normal fertility. Phytoestrogens are plant-based estrogenic compounds that at times can behave similarly to endogenous estrogen or estradiol. Cell culture work has demonstrated that phytoestrogens may have deleterious effects on oviduct function which is quite different than the effect of estradiol.[49] Hence, it is possible that some of the negative impact of elevated CP may have potentially been confounded by phytoestrogens, depending on the source and type of CP supplement used in the diet.

The take home message regarding protein feeding is that there is still a lot to be learned regarding the interaction of protein levels, protein fractions and fertility in dairy cattle. Proper balancing of rations to optimize metabolizable protein and amino acid profiles serve to limit the total amount of crude protein supplementation necessary to achieve high milk production. Reducing total crude protein in rations also creates opportunities for incorporating more structural and nonstructural carbohydrates in rations. The benefits of specific amino acids in regards to reproductive performance are still largely unclear but certain amino acids like methionine, cystein, and histidine appear to play key roles in improving the structural integrity of the hoof wall and may reduce the risk of lameness, thus improving estrus expression, energy balance and presumably, overall reproductive efficiency. In addition, high producing postparturient dairy cows likely are unable to produce adequate quantities of metabolizable protein, reducing milk production but also reducing hoof quality.

Miscellaneous

- Monensin – Monensin is a very common feed additive in most dairies today and is unique in that it has a label claim for increased milk production efficiency in dairy cows. Monensin works by decreasing methane production and reducing the population of acetic and butyric acid producing bacteria. The result is increased propionate, reduced acetate-to-propionate ratio, and a general reduction in wasted energy of digestion, which may lead to increased milk production, reduced milk fat and lower feed intake. Duffield et al., recently published a meta-analysis covering 20 research trials and reported no effect of monensin on reproductive performance as evaluated using first service conception risk or days to conception.[50]

- Biotin – Biotin is a water soluble B vitamin that is normally synthesized in the rumen and plays a key role as a cofactor in enzymatic systems required for gluconeogenesis, protein synthesis and lipogenesis. In addition, it has been shown to be an essential factor of the intracellular cementing substance that bonds the keratin leaflets of hoof horn and contributes to healthier hoof horn production.[51] During early to peak lactation, supplementation of biotin may be desirable since the lower pH of the rumen that is usually observed as a consequence of aggressive carbohydrate feeding may diminish the rumen's production ability of biotin. Supplementation with 20 mg/day has been shown to increase milk production and reduce calving-to-conception interval in lactating dairy cattle.[51]

- Choline – Choline is a water soluble nutrient, often mistakenly placed in the water-soluble vitamin group. It is utilized for formation of phosphatidylcholine which is necessary for the formation of lipoproteins such a apolipoprotein b in ruminants. The two pathways for phosphatidylcholine synthesis are 1) combination of choline with diacylglycerol or 2) the methylation of phosphatidylethanolamine with S-adenosylmethione as a methyl donor.[52] It has been suggested that provision of rumen protected choline in transition dairy cows would ensure an adequate choline supply and spare methyl donors such as methionine, resulting in enhanced transportation of fatty acids from the liver, enhanced hepatic oxidation of fatty acids and a consequent improvement in gluconeogensis as a result of improved hepatic health and function. Research has suggested that rumen-protected choline may help prevent and potentially alleviate hepatic accumulation of fatty acids in transition dairy cows.[52,53] Presumably, if liver health is improved, gluconeogenesis should be enhanced and cattle should make a smoother transition from the dry period to lactation, resulting in earlier cyclicity and improved postpartum reproductive function. Thus far, field results tend to show an improvement in milk production but reproductive impact still needs more work. Technical research report 2005:2 from Balchem (shown on their website - http://balchem.com/images/pdfs/TechResearchRpt2005-2.pdf) describes a clinical trial in Tulare, Ca that reported an improvement in first service conception risk and a tendency to see a larger percentage of cows pregnant by 6 months.

- Gossypol – Gossypol is a toxic, polyphenolic compound found in the cotton plant and occurs in both a protein bound form and a free form. The free form is the more toxic form and can vary from plant to plant and between cotton varieties. The free form is highest in whole seeds and varies from 0.01 to 1.7% or more and is usually higher in Pima than in Upland varieties of cotton. Gossypol disrupts cell membrane and mitochondrial metabolism and increases red blood cell fragility. It is usually toxic to all animals but is most toxic to monogastrics, immature ruminants and poultry. Classically, gossypol causes damage to the cardiac, renal, hepatic and reproductive systems. In ruminants, the threshold for toxicity is much higher than in monogastrics for all systems except reproductive function in bulls. In bulls, seminiferous tubule damage and midpiece abnormalities have been observed in sperm following the consumption of 8 g/day of free gossypol.[54-56] If whole cottonseed is included at 15% of the diet dry matter and DMI is 30 lbs, bulls can easily consume more than 10 g/ day of free gossypol resulting in poor sperm motility, morphology and depressed fertility. While the impact in females is less severe, high levels of gossypol have also been shown to depress conception risk and calving-to-conception intervals in Holstein cattle fed 3.1 and 6.9% of the diet DM from whole Upland and cracked Pima seed, respectively.[57] The author's approach to feeding whole cottonseed is to limit the total cotton products (cottonseeds and cottonseed meal) fed to 10% or less of the ration dry matter, to preferentially use Upland over Pima seed, and to ensure that adequate effective fiber is present to retain the whole seeds in the rumen to enhance digestibility and to improve the binding of gossypol to proteins within the rumen.

Conclusion

Nutrition can and does play a key role in driving reproductive performance. Obviously, frank nutrient deficiencies can have direct negative impacts on fertility, primarily mediated through insufficient energy and its effects on cyclicity. Improving energy balance by careful attention to specific nutrient levels including both structural and nonstructural carbohydrates (maintaining sufficient effective fiber intake to ensure a healthy, well-functioning rumen and consistent levels of feed intake while balancing the need for fermentable substrates for sufficient propionate production and total metabolizable energy needs) as well as providing a proper blend of RDP and RUP to meet metabolizable protein needs without overt excesses is key. In order to maximize early return to cyclicity in lactating dairy cows, the period of NEB must be shortened and decreased in magnitude. While there are many opinions regarding the most appropriate combination of feed additives, fatty acids, and specific ration balancing targets, a critical goal is to minimize the prepartum depression in feed intake and to maximize feed intake in the postpartum period. Properly balanced rations and their appropriate delivery (adequate feed bunk space as well as attention to cow comfort issues) must be present to achieve both high milk production and reproduction. Targeted provision of supplemental nutrients such as key fatty acids and additional vitamins (A and E) or microminerals such as selenium during the transition and early lactation periods can and often do lead to improved cow health and reproductive potential in addition to supporting increased levels of milk production.

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