MODERATE ENERGY DRY COW DIETS MAY IMPROVE POSTPARTUM HEALTH

N. B. LITHERLAND
Dairy Nutrition Extension and Research
University of Minnesota
Department of Animal Science

INTRODUCTION

The objective of this paper is to suggest a three pronged approach to improving the health and productivity of the periparturient dairy cow. An attempt is made to combine feeding management (high straw moderate energy diets during the dry period) along with the use of neutraceutical and pharmaceutical compounds to increase hepatic fatty acid oxidation and reduce adipose tissue mobilization. Maintaining dry matter intake, moderating prepuntum and postpartum blood non-esterified fatty acids (NEFA), maximizing hepatic fatty acid oxidation, maintaining immune function, and minimizing stress are important goals for improving the health and productivity of the periparturient dairy cow.

The main objective of feeding during the dry period, in addition to growth of the fetus and mammary gland, is to prepare the cow for the subsequent lactation. Changes in hormones, metabolism, and immune function around the time of calving result in challenges to the maintenance of homeostasis in early lactation. Failure of dairy cattle to successfully transition into lactation results in reduced efficiency of production by disallowing fresh cows to reach their full genetic potential, increasing the incidence of metabolic disorders and disease, and premature culling. Transition cow research over the last fifteen years has examined strategies to improve postpartum productivity and health. Most strategies focus on maintaining dry matter and thus energy intake in the hope of moderating the flux of NEFA from adipose. Changes in metabolism occur weeks prior to calving. A full understanding of factors inherent to the biology of the modern dairy cow prior to parturition still eludes us.

It is important to ask the question “Who is our modern dairy cow and why is she the way she is?” More importantly, how can we manage her appropriately to maximize her potential? If we look back into history and hypothesize about the great grandmother of the modern dairy cow we can possibly envision her as a seasonal breeder, due to seasonal forage quality, and thus energy availability, and likely calved in the spring. She likely consumed a low energy high fiber diet of dormant grasses native to Northern Europe during her dry period. Her milk production was enough to sustain her calf up until weaning. Modest milk production and the availability of a primarily forage low energy diet resulted in development of metabolic machinery that was capable of meeting her needs. She was likely rarely overconditioned and her diet was low in fat resulting in limited development of her liver’s ability to metabolize large amounts of mobilized body fat that is typical of our modern dairy cow.
Our modern dairy cow has changed greatly even over the last thirty years. We have tried to develop feeding strategies to prepare the cow to make a successful transition into lactation by maximizing prepartum intake and feeding diets with higher energy density only to be frustrated by the lack of success (Friggens et al., 2004). The “steam up strategy” for feeding dry cows is to increase energy density of prepartum diets by increasing the non-fibrous carbohydrate content and to maximize feed intake before parturition (Grummer et al., 2004). Data generated from Illinois and groups around the world indicate that cows that are moderately overfed (>140% of NE\textsubscript{L} requirements) during the dry period, even in the absence of obesity, may be at a greater risk for periparturient health problems (Dann et al., 2005; Dann et al., 2006). Dry matter and thus energy intake begins to decrease weeks prior to calving resulting in negative energy balance and increased blood NEFA. The dairy cow has a limited capacity to oxidize NEFA in the liver resulting in esterification of NEFA and eventual hepatic lipidosis (fatty liver) if circulating NEFA go unchecked. Perturbations in liver function may activate the immune system which may act to further decrease DMI compounding negative energy balance.

It is critically important to understand interactions among nutrition, metabolism, and the immune system. In this paper, a four pronged approach is suggested to optimize the chance for a successful transition into lactation.

- Feed a moderate energy diet, containing 30-50 percent wheat straw during the entire dry period to maintain dry matter intake and minimize overconsumption of energy.
- Possibly treat cows with a PPAR-\(\alpha\) agonist to increase hepatic fatty acid oxidation.
- Possibly treat cows with a PPAR-\(\gamma\) agonist to reduce lipid mobilization from adipose tissue.
- Further understanding of the effects of the immune system on feed intake and NEFA mobilization.

SUCCESS OF MODERATE ENERGY DIETS FED DURING THE DRY PERIOD

Data collected at the University of Illinois over the last ten years demonstrates that cows fed even moderate-energy diets (0.69-0.73 Mcal NE\textsubscript{L}/lb DM will consume 40-80% more NE\textsubscript{L} than required during both far-off and close-up periods (Drackley and Janovick Guretzky, 2007). Prolonged consumption of energy in excess of that required during the dry period can result in reduced postpartum success due to increased incidence of health disorders. Additionally, higher feed energy costs are observed with no measurable return on investment. Higher energy or steam-up feeding during the close-up period has been unsuccessful in improving the health and production of transition dairy cows. Data from Illinois (Douglas et al., 2006; Dann et al., 2006) indicates lower post-partum dry matter intake and slower increases in milk production in cows that were overfed energy during the dry period. Over-feeding results in negative responses of metabolic indicators, such as high NEFA in blood and greater liver lipid accumulation postpartum (Douglas et al., 2006; Janovick-Guretzky et al., 2006). Additionally, alterations in hepatic metabolism (Litherland et al., 2003) and gene-level responses (Loor et al., 2005, 2006) indicate
changes occurring in cows due to prepartum energy intake. It appears the exposure of liver to elevated NEFA before parturition may allow cows to adjust hepatic metabolism towards oxidation and away from triglyceride synthesis. Grum et al. (1996); Douglas et al. (2006); and Dann et al. (2006) all showed that cows with modestly restricted energy intake postpartum resulted in improved liver lipid metabolism. Perhaps a better strategy would be to prepare cows for inevitable changes in energy metabolism, specifically hepatic fatty acid oxidation and gluconeogenesis, associated with calving and lactation.

Research groups around the U.S. (Dann et al., 2006; Holcomb et al., 2001) as well as in other countries (Beever, 2006; Agenäs et al., 2003; Rukkwamsuk et al., 1998; Kunz et al., 1985) have observed improved postpartum production and health in cows fed moderate energy dry cow diets during the dry period (Table 1). Formulating diets that are relatively low in energy density (0.59-0.63 Mcal NE\textsubscript{i}/lb DM) by including approximately 30 percent wheat straw allows cows to eat free choice without greatly exceeding energy requirements. The concept is to allow cows to meet but not exceed energy requirements by consuming a bulky diet that provides sufficient rumen fill. High straw diets should force dry cows to stop eating due to rumen fill before they greatly exceed their requirement for energy intake.

The effects of high straw diets on maintaining rumen volume should be beneficial. Maintaining rumen volume and maintaining rumen muscle tone during the dry period might be an extremely beneficial byproduct of moderating energy intake using high straw diets. Additionally, it may be important for cows to remain accustomed to consuming large amounts of forage. Dairy cows spend a considerable portion of their day eating during lactation. Maintaining this feeding behavior by offering cows a high fiber diet ad libitum might be beneficial as it minimizes the change in their daily routine as they freshen. Additionally, field evidence suggests the rumen fill due to the reduced rate of passage of high straw diets may decrease the incidence of displaced abomasum by providing some level of rumen fill even as feed intake decreases.

Recent increases in ingredient costs underscore the advantages of reducing feed costs during the dry period and maximizing health and production efficiency postpartum. A cost comparison of a high straw moderate energy dry cow diet with a higher energy dry cow diet is provided in Table 2. Feeding a moderate energy diet versus a higher energy diet to dry cows would result in an estimated feed savings of almost $0.40/cow/day. A herd averaging 30 dry cows in the dry cow pen would realize an annual savings of $4380 in reduced feed costs. This estimate does not account for added health benefits, reduced veterinary bills, and the potential for greater milk yield in the subsequent lactation.

**PRACTICAL APPLICATIONS OF HIGH STRAW DIETS FOR DRY COWS**

Recommendations for proper feeding of moderate energy wheat straw diets are based on the authors personal experience and recommendations found elsewhere (Drackley and Janovick-Guretzky, 2007 and Beever, 2006).
The goal of this feeding strategy is to provide a low energy high fiber total mixed ration that is fed at an ad libitum rate that meets but does not greatly exceed nutrient requirements.

Begin feeding a high straw moderate energy diet at dry off and continue through until calving. High straw diets initiated during the close-up period (3 wk prior to calving) may result in lower than expected intakes as cows need time to adapt to these diets and might be detrimental to cows calving early.

Straw needs to be coarse and processed to a length of 2 inches or less to prevent sorting. Most TMR mixers do an adequate job of processing straw, however, there have been some reported challenges in adequately processing straw when feeding small numbers of dry cows.

Wheat straw is preferred over other types of roughages due to its physical properties, low energy content, and good palatability.

Dry matter intake is typically 25 to 30 lb per day. Intakes may exceed 30 lb DM per day in far-off dry cows.

Energy density: 0.59-0.63 Mcal NE\textsubscript{L}/lb DM.

Crude protein content: 12 to 14% with metabolizable protein exceeding 1,000 g/day. Consider increasing the protein in the diet if growing heifers are mixed with mature dry cows.

Starch content: 12 to 16% of DM.

Forage NDF: 40 to 50% of total DM, or 10 to 12 lb daily (0.7 to 0.8% of body weight).

Total ration DM content: <55% (add water if necessary). Additional water will help prevent sorting and improve palatability.

Follow NRC, 2001 recommendations for mineral supplementation. Anionic salts should be added to prevent milk fever. Anionic salts can be mixed into the dry cow diet three weeks prior to calving.

This system works best for producers who are relying on corn silage as a primary forage. The combination of straw and corn silage is highly palatable, provides an appropriate blend of energy and forage, and is low in potassium.

Ensure that adequate bunk space is provided to minimize competition.

Push up feed regularly to minimize sorting and to ensure that cows have ad libitum access to feed.

Bunks and feed aprons may need to be modified to account for the increased bulkiness of the diet.

**DRY COWS AND INSULIN RESISTANCE**

Consumption of a diet that greatly exceeds energy requirements results in excessive accumulation of visceral adipose and insulin resistance similar to type II diabetes in humans. Insulin resistance results in a reduced ability to maintain homeostasis. Insulin resistance describes a less than normal biological response to a physiological level of insulin (Kahn, 1978). The metabolic profile during early lactation includes low concentrations of serum insulin, plasma glucose, and liver glycogen and high concentrations of serum glucagon, adrenaline, growth hormone, plasma β-hydroxybutyrate, NEFA, and liver triglyceride. During late gestation and early lactation,
flow of nutrients to the calf and mammary gland are the highest priority. The high priority of the calf and mammary gland for glucose results in reduced insulin sensitivity in peripheral tissues. This reduced insulin sensitivity may play an important role in excessive NEFA mobilization and the development of hepatic lipidosis and ketosis. Insulin stimulated lipogenesis and inhibits ketogenesis in liver (Brockman, 1978). Insulin resistance in peripheral tissue may be a normal adaptation during late pregnancy to facilitate glucose sparing for the mammary gland (Bauman and Elliot, 1983). Insulin resistance developed during late pregnancy in the form of decreased tissue responses to insulin and continued into early lactation (Smith, 2004). Additionally, tissue responses to insulin in dairy cows may be less prior to calving than in early lactation (Smith et al., 2006).

Overfeeding energy to dairy cows during the dry period may increase insulin resistance in adipose tissue, resulting in increased circulating NEFA, depression in DMI, and greater risk for liver lipid accumulation and associated disorders. Obese dry cows have poor appetites postpartum and have been associated with hypoglycemia and hypoinsulinemia. During late gestation, increased serum concentrations of the hormones estradiol, progesterone, and prolactin affect the sensitivity of peripheral tissues to insulin (Hayirli, 2006). Cows in excessive body condition are at greater risk for metabolic disorders. Adipose tissue is mobilized in the form of NEFA, which must be metabolized by the liver resulting in liver lipid accumulation, ketosis, and reduced liver functions such as gluconeogenesis, ureagenesis, and hormone degradation (Drackley et al., 2001). Drackley and Janovick-Guretzky (2007) suggested that over-consumption of energy during the dry period may result in excessive accumulation of internal adipose tissue putting those cows at greater risk for type II diabetes and insulin resistance. It is likely that there is variability in the site and extent of adipose tissue storage among cows predisposing them to poor health. Visceral adipose may be mobilized at a greater rate than subcutaneous adipose. Body condition scoring, therefore, does not tell the whole story in regards to adipose tissue mobilization.

**LIVER LIPID METABOLISM**

Circulating NEFA are a substrate for oxidation and are used by many tissues as an energy source during periods of negative energy balance. Uptake of NEFA by liver is related to blood flow and concentration (Reynolds et al., 2003). Fatty acids taken up by the liver can be completely oxidized to form ATP and the byproduct carbon dioxide, partially oxidized to ketones (primarily acetoacetate and β-hydroxybutyrate), or be reesterified to form triglycerides. The liver has a limited capacity to completely oxidize fatty acids and the ruminant liver has a low ability to package and export triglycerides in very low density lipoproteins. Elevated NEFA in blood results in the overwhelming of pathways of oxidation resultant increases in storage as triglyceride and as a result cows in negative energy balance are predisposed to fatty liver and ketosis. Liver lipid accumulation starts weeks before calving and typically peaks at around 10 to 14 days postpartum. Increasing hepatic oxidative capacity should reduce liver lipid accumulation.
NEUTRACEUTICAL AND PHARMACEUTICAL APPROACHES TO IMPROVED TRANSITION COW HEALTH

Enhancing hepatic oxidation of fatty acids

Minimizing triglyceride (TG) accumulation in the liver of periparturient cows is an important step towards meeting the goal of a smooth transition into lactation. Enhancing the ability of liver to oxidize fatty acids should decrease TG accumulation in the liver. Peroxisomal β-oxidation may be part of a strategy to dispose of increased NEFA flux during negative energy balance (Grum et al., 2002). Although peroxisomal β-oxidation is energetically less efficient than mitochondrial β-oxidation, peroxisomal β-oxidation has been suggested as a mechanism of the disposal of NEFA taken up in excess of hepatic capacities for esterification and mitochondrial β-oxidation (Osmendsen et al., 1991). Peroxisomal β-oxidation has been shown to be relatively more prevalent in ruminants than in rodent models (Grum et al., 1994). Peroxisomal oxidation in liver homogenates from cows represented 50% of the total capacity for the initial cycle of β-oxidation of palmitate (Grum et al., 1994). Together, these data suggest that peroxisomes may play an important role in oxidation of long-chain fatty acids in cows during the transition period.

Peroxisome proliferator-activated receptors (PPAR) are nuclear proteins that belong to the superfamily of nuclear hormone receptors and function as ligand-dependent transcription factors. Therefore, PPAR control the expression of genes implicated in intra- and extracellular lipid metabolism such as genes encoding for enzymes involved in mitochondrial and peroxisomal β-oxidation pathways (Schoojans et al., 1996). PPAR-α is abundant in liver and plays a role in the regulation of peroxisomal and mitochondrial fatty acid oxidation. When administered to rats and mice, compounds that act as PPAR-α agonists produce a dramatic increase in the size and number of peroxisomes and increase the capacity of hepatocytes to metabolize fatty acids by inducing mitochondrial and peroxisomal enzymes for β-oxidation (Green, 1995). Both naturally occurring and synthetic PPAR agonists exist. A wide variety of fatty acid molecules, both saturated and unsaturated, can serve as PPAR-α agonists. Grum et al. (2002) indicated that 6% dietary fat from whole raw soybeans plus animal fat was not sufficient to elicit peroxisomal β-oxidation in liver of dairy cows. In rodents, polyunsaturated fatty acids (PUFA) are much more potent activators of PPAR-α than are saturated fatty acids (Kliwer et al., 1997). Dietary PUFA have been shown to reduce lipid accumulation in the liver, increase fatty acid oxidation in the liver and increase total body glycogen storage (Jump and Clarke, 1999).

Another group of compounds that are potent PPAR-α agonists are the fibric acid derivatives such as clofibrate (Abbiyik et al., 2004). Clofibrate increases hepatic peroxisomal β-oxidation in rats by as much as 10 fold when either fed or injected daily (Lazarow and De duve, 1976; Mannaerts et al., 1979).

Limited published work is available evaluating the use of PPAR-α agonists in periparturient dairy cows. Workers in Florida fed 150 g/d of a trans-C18:1 to cows starting four weeks prior to calving and observed increases in hepatic PPAR-α mRNA
content during the first month of lactation (Selberg et al., 2005). Work conducted at the University of Illinois using Holstein calves showed that clofibrate and PUFA from fish oil modestly increased rates of oxidation of palmitate in liver slices (Litherland et al., 2006). Feedstuffs containing PUFA or specifically omega-3 fatty acids such as flax seed may provide beneficial effects on liver lipid metabolism during the peripartureint period. Workers at Wisconsin were able to demonstrate that omega-3 fatty acids increase fatty acid oxidation in vitro and show potential to moderate development of hepatic lipidosis (Mashek and Grumer, 2003). Dry cows fed flaxseed both prepartum and postpartum had lower liver lipids and higher liver glycogen postpartum than those fed saturated fat or no supplemental fat (Petit et al., 2007). Danish researchers attempted to prime metabolic machinery for NEFA metabolism during the dry period by feeding saturated or unsaturated fat (Andersen et al., 2008). Results from the Danish study indicated that feeding linseed in the dry period was not beneficial and that saturated fatty acids were more beneficial. These results are similar to that of Grum et al. (1996) who demonstrated that dry cows fed a relatively large amount of saturated fat had increased capacities for hepatic fatty acid oxidation and lower liver triglyceride accumulation postpartum.

Administration of PPAR-α agonists may provide an ancillary route for the oxidation of fatty acids by increasing both peroxisomal and mitochondrial pathways, although this remains to be tested in periparturient dairy cows.

Reducing Body Fat Mobilization

Nutritionists and producers have operated under the hypothesis that cows need to have some body fat reserves to support peak milk production in early lactation. The challenge has been to control the amount of fat that is mobilized and the subsequent load of NEFA presented to the liver. Reduced reliance on body fat reserves during early lactation may reduce the metabolic strain on the liver.

Peroxisome proliferator activated receptor gamma (PPAR-γ) belongs to a subfamily of the nuclear-receptor family that regulated gene expression in response to ligand binding (Hammarstedt et al., 2005) and is highly expressed in bovine adipose tissue (Sundvold et al., 1997). Activation of (PPAR-γ) initiates adipocyte differentiation, stimulates insulin action, and decreases the release of NEFA from the adipocyte (Houseknecht et al., 2002). Naturally occurring PPAR-γ agonists include fatty acids and prostaglandins, however, thiazolidinedione (TZD), is a family of potent synthetic PPAR-γ agonist (Bernardo and Minghetti, 2008).

Limited work using PPAR-γ has been done in ruminants. In steers injected with tumor necrosis-factor-alpha (TNF-α) to induce insulin resistance, Kushibiki et al., (2001) observed decreased circulating NEFA, insulin, and glucagon in steers treated with TZD when compared with controls. Workers at Cornell administered TZD to dry cows and observed decreased plasma NEFA concentrations and increased DMI during the peripartum period (Smith et al., 2007). Administration of TZD prepartum also decreased liver TG and increased body condition score postpartum (Smith et al., 2007). Application of PPAR-γ in dairy cattle may be a useful tool to limit NEFA mobilization.
Combination of PPAR-α and PPAR-γ on liver metabolism

Increased hepatic fatty acid oxidation combined with reduced flux of circulating NEFA should combine to result in a reduced incidence of fatty liver and ketosis. Future work should attempt to confirm this hypothesis and to determine the ideal compounds, dosage, and duration of treatment prior to calving that will result in the optimal response. These compounds have been researched in dairy cattle, but have not yet been approved for use. The author is not recommending these techniques be applied, but simply giving a glimpse into the future and the tools that may become available.

Notes on PPAR Administration

Feeding naturally occurring PPAR-α agonists such as omega-3 fatty acids found in fish oil, linseed oil, and other sources may be the most practical method of delivery. Protection from ruminal biohydrogenation of these fatty acids would be necessary to ensure that the appropriate amount of intact long chain polyunsaturated fatty acids are being absorbed. It may be possible to incorporate synthetic PPAR-α agonists such as clofibrate, into the diet as well, but the likely route of delivery is through an injection. Protection from rumen microbes for synthetic compounds is essential to ensure they are delivered intact at the site of absorption. Synthetic PPAR agonists may negatively alter rumen fermentation (Dokianakeis et al., 2004; Fountoulakis et al., 2004; Drillia et al., 2005).

Continued work needs to focus on the long term effects of PPAR-α and PPAR-γ agonists on cattle health and subsequent secretion of these compounds into milk and manure. The correct dosage and duration of treatment of PPAR-α and PPAR-γ agonists needs to be further elucidated to optimize their effectiveness. Finally, continued development and application of genomics may allow for identification of individuals or cow families that would benefit from treatment with PPAR-α and PPAR-γ agonist allowing for greater selectivity of treatment administration.

LIVER LIPID ACCUMULATION AND CHANGES IN IMMUNE FUNCTION IN THE PERIPARTURIENT DAIRY COW

A more thorough understanding of immune function in the periparturient cow may help us develop strategies to improve postpartum health and productivity. Metabolic and environmental stressors have a negative effect on immune function. Immune function is reduced in periparturient dairy cows and may be a normal function of the processes of colostrogenesis and parturition. Suggested reasons for the reduction in immune function include changes in hormones due to parturition, changes in management, nutrition, and negative energy balance. Additionally circulating NEFA has negative effects on peripheral tissue that may elicit an immune response. Liver health and function is likely a key player in immune function around the time of calving. It is plausible that oxidative stress occurs in hepatocytes coping with large amounts of NEFA as well as those with large intracellular lipid droplets that may elicit an immune response.
Concentrations of total lipid and triglyceride in liver postpartum were positively correlated with bilirubin and ceruloplasmin and negatively correlated with paraoxanase measured postpartum in cows fed diets varying in energy density during the dry period (Janovick Guretzky et al., 2007). The authors concluded that overfeeding during the dry period may have compromised liver function postpartum and contributed to inflammation and development of fatty liver. Gene expression in liver samples from the same Illinois study showed that ad libitum feeding of a higher energy diet upregulated a number of genes associated with liver triglyceride synthesis (DGAT1) and proinflammatory cytokines (TNFAIP3) (Loor et al., 2006). Even moderate overfeeding of energy during the dry period, in the absence of obesity, results in metabolic changes predisposing cows to fatty liver, which may compromise health during the periparturient period.

Increased concentrations of circulating NEFA prior to calving may be associated with changes in immune function. The acute phase response is associated with numerous changes in lipid and glucose metabolism, such as decreased cholesterol, accelerated lipolysis, and increased NEFA in plasma (Hardardottir et al., 1994). Liver macrophages known as Kupffer cells are the first to respond to inflammatory conditions by release of a variety of cytokines such as TNF-α, interleukin-1 (IL-1), and interleukin-6 (IL-6), which contribute to the production of acute phase proteins by liver hepatocytes. Examples of acute phase proteins include serum amyloid A (SAA), haptoglobin, and calcitonin gene-related peptide (CGRP). The SAA is associated with plasma high density lipoproteins and has been proposed to participate in detoxification of plasma toxins (Baumberger et al., 1991). Haptoglobin binds hemoglobin and prevents utilization of iron by bacteria. Calcitonin gene-related peptide is associated with hyperglycemia and is known for its anti-inflammatory properties.

Cows with experimentally induced fatty liver had greater plasma TNF-α four days prior to calving, and at some point during the periparturient period had greater concentrations of plasma SAA, haptoglobin, and lower concentrations of calcitonin gene-related peptide (CGRP), prostaglandin, estrogen, cortisol, and TNF-α (Ametaj et al., 2005). These results indicate that the acute phase response occurs in cows with fatty liver. Administration of TNF-α is associated with decreased appetite and increased release of NEFA from adipose tissue (Kushibiki et al., 2002). A greater understanding of immune function is critical to developing strategies to manage dry cows better. Strategies that moderate immune function prior to calving may be beneficial.

AREAS OF FUTURE RESEARCH

1. Minimal attention has focused on the effects of nutrition and management during late lactation on the success of the subsequent lactation. First calf heifers that are still growing, overweight late lactation cows, and high producing cows that are too thin at dry off all offer unique challenges that a typical 40-60 day dry period may not address. Feeding late lactation cows to more closely meet their requirements may further improve moderate energy feeding strategies during the dry period resulting in greater success post-partum.
2. The use of neutraceuticals and pharmaceuticals to improve periparturient cow metabolism and health is exciting and should be explored more thoroughly.

3. Improvements in gene expression technology may eventually result in the ability to predict if an individual is at risk for a metabolic disorder or disease and offer the opportunity to manage individuals to optimize health and productivity of the herd.

4. Further understanding of factors regulating dry matter intake at calving is critical to improving transition cow success.

5. The effects of social interactions associated with pen movements, diet changes in the dry period, and cow comfort need to be better understood.

TAKE HOME MESSAGES

- Despite many years of research and varied approaches, periparturient health in dairy cows remains a challenge on most farms.
- Diets fed during the dry period containing 30-50% wheat straw moderate energy intake and promote greater DMI postpartum and may improve health.
- Increasing hepatic fatty acid oxidation and reducing adipose tissue mobilization by using PPAR-α and PPAR-γ agonists in dairy cows prior to calving is interesting and should be explored more thoroughly.
- Strategies discussed above that assist in maintaining homeostasis should improve immune function around the time of calving which would be beneficial to the health and well-being of dairy cattle.

Table 1. Effects of moderate energy intake during the dry period on general trends in post-partum dry matter intake (DMI), Milk production, energy balance (EB), non-esterified fatty acids (NEFA), and insulin.

<table>
<thead>
<tr>
<th>Location</th>
<th>Author</th>
<th>DMI</th>
<th>Milk Production</th>
<th>EB</th>
<th>NEFA</th>
<th>Insulin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>Dann et al., 2006</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
<td>NC</td>
</tr>
<tr>
<td>Illinois</td>
<td>Douglas et al., 2006</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
<td>NC</td>
</tr>
<tr>
<td>Illinois</td>
<td>Janovick et al., 2006</td>
<td>NC</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>---</td>
</tr>
<tr>
<td>Florida</td>
<td>Holcomb et al., 2001</td>
<td>↑</td>
<td>↑</td>
<td>---</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Sweden</td>
<td>Anenäs et al., 2003</td>
<td>NC/↑</td>
<td>↑</td>
<td>↑</td>
<td>NC</td>
<td>↓</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Dewhurst et al., 2000</td>
<td>NC</td>
<td>NC</td>
<td>---</td>
<td>---</td>
<td>↓</td>
</tr>
</tbody>
</table>
Table 2. Estimated current (at time of publication) costs of far off diets differing in energy density. Based on dietary treatments found in (Dann et al., 2006). Estimates are based on 27 pounds of dry matter intake. Diets were formulated to meet (100NRC) energy requirements or exceed (150NRC) nutrient requirements for far-off dry cows.

<table>
<thead>
<tr>
<th>Item</th>
<th>100 NRC</th>
<th>150NRC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of ration DM</td>
<td>Cost/lb DM</td>
</tr>
<tr>
<td>Alfalfa silage</td>
<td>41.68</td>
<td>0.08</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>---</td>
<td>0.08</td>
</tr>
<tr>
<td>Corn silage</td>
<td>21.10</td>
<td>0.06</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>26.14</td>
<td>0.045</td>
</tr>
<tr>
<td>Cottonseed</td>
<td>---</td>
<td>0.25</td>
</tr>
<tr>
<td>Ground shelled corn</td>
<td>7.20</td>
<td>0.11</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>3.05</td>
<td>0.23</td>
</tr>
<tr>
<td>Expelled soy</td>
<td>---</td>
<td>0.21</td>
</tr>
<tr>
<td>Soy hulls</td>
<td>---</td>
<td>0.06</td>
</tr>
<tr>
<td>Mineral mix</td>
<td>0.82</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>Total estimated daily cost</strong></td>
<td>2.07</td>
<td>2.44</td>
</tr>
</tbody>
</table>

Composition

<table>
<thead>
<tr>
<th></th>
<th>CP, 15.8</th>
<th>16.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF</td>
<td>31.8</td>
<td>26.1</td>
</tr>
<tr>
<td>NDF</td>
<td>46.5</td>
<td>38.1</td>
</tr>
<tr>
<td>Starch</td>
<td>13.2</td>
<td>21.4</td>
</tr>
<tr>
<td>NEₜ (Mcal/kg)</td>
<td>1.30</td>
<td>1.59</td>
</tr>
</tbody>
</table>

REFERENCES


Drackley, J. K. and N. A. Janovick Guretzky. 2007. Controlled energy diets for dry cows. 2007 Western dairy management conference proceedings Pg 7-16.


