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Nutrition and Health of Dairy Animals

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1. Introduction

Modern breeds of dairy animals are able to produce huge amount of milk. In attempt to consume, digest and metabolize enough nutrients to satisfy lactation needs, those animals are exposed to serious stress conditions that can affect their health. Health problems which arise from those conditions are mainly related to impaired ability to metabolize enough nutrients to compensate for those lost in milk. They are known as metabolic or production diseases and may be of great economic importance in milk production systems.

Although metabolic diseases have become a common problem on dairy farms, they still require a serious attention to be controlled. The incidences of these disorders can be reduced by proper nutrition of animals. Also, some of the specific strategies in feeding practice offer additional advantages in prevention of nutrition-related metabolic diseases.

2. Nutrition-related metabolic disorders, their etiology and consequences

The most important metabolic diseases in dairy cows, ewes and goats can be discussed as energy and/or fiber related, lipid related or vitamin and mineral related disorders. However, they are not easily categorized according to their cause, thus the pathogenesis and hallmarks of each disease should be considered for their categorization. Energy related disorders (related to energy density of the diet or feed intake) include fatty liver and ketosis, rumen acidosis, laminitis, displaced abomasums and milk fat depression. As energy density and fiber content of the diets are often inversely related, most of these diseases can be considered as fiber related too. Fatty liver and ketosis also can be categorized as lipid related disorders due to changes in lipid metabolism in affected animals (Grummer, 1993). The most important mineral/vitamin related disorders are hypocalcaemia, hypomagnesaemia, udder edema, retained placenta and metritis. Not all of them are ultimately caused by mineral composition of the diet, but may be prevented by manipulation of minerals or vitamins in the diet. Broken homeostatic mechanisms often become major etiological factors in the

development of metabolic disease, and consequences varies from reduced production and impaired reproductive performances to increased risk to develop other diseases.

2.1. Fatty liver

Fatty liver (hepatic lipidosis, fat cow syndrome) is a metabolic disorder characterized by a high content of lipids and triglycerides in the liver (Ingvartsen, 2006). The disease occurs in periparturient period, primarily in the first 4 weeks after calving (Grummer, 1993), and as a secondary disease of other production diseases that depress appetite or increase body fat mobilization. The clinical symptoms comprise depression, lack of appetite and weight loss, and the cows are weak and apathetic (Radostits et al., 2000). Most cows suffer from non-specific clinical signs including reduced rumen motility and decreased milk yield. However, this disease occurs especially in its subclinical form and can be a problem for up to 50% of cows in early lactation (Ingvartsen, 2006).

Risk factors for fatty liver in dairy cows may be nutritional, managerial, and genetic. Prepartum risk factors include obesity, severe feed restriction, feeding excess energy, and long calving interval. Postpartum risk factors are different diseases and infection, fasting and feed restriction, as well as ketogenic diets and sudden feed changes (Bobe et al., 2004). Among the highest risk factors of fatty liver is a high rate of mobilization of body lipids around calving in overconditioned cows which have been overfed in late lactation and the dry period and had low feed intake around calving (Ingvartsen, 2006). Increased prepartum body weight gain or body condition increase liver fat content and indicate increased risk of fatty liver and related disorders. Therefore, the primary nutritional risk factor for fatty liver is obesity. In obese cows, lipolysis of adipose tissue is increased more during peripartal period than in cows with normal body condition. Obese cows have a greater decrease in feed intake around calving and, therefore, have a more severe negative energy balance (Bobe et al., 2004). During the negative energy balance body fat is mobilized into the bloodstream in the form of non-esterified fatty acids (NEFA). NEFA are taken by the liver in proportion to their supply, but the liver does not have capacity sufficient to oxidize and use all amount of NEFA for energy. Therefore, cows are predisposed to accumulate NEFA as triglycerides within the liver when large amounts of NEFA are released from adipose tissue (Overton & Waldron, 2004). Rate of triglyceride synthesis is proportional to plasma NEFA concentration, thus fatty liver is likely to develop when plasma NEFA are elevated (Grummer, 1993).

Severe negative energy balance caused by low feed intake around calving leads to increase in body fat mobilization and plasma NEFA concentration. Thus, the severity of fatty liver may be reduced if drop in feed intake before calving is prevented (Bertics et al., 1992).

Diets deficient in cobalt (Co) have been shown to cause fatty liver in sheep. It has been termed as ovine white liver disease. Hepatic lipidosis in goats due to feeding low levels of Co in their diet has also been reported (Johnson et al., 2004).

Fatty liver is associated with decreased health status and reproductive performance. In severe cases, milk production and feed intake are also decreased (Bobe et al., 2004).

Although fatty liver is often a reversible condition, it predisposes cows to reduced liver function and to a number of other production diseases (Ingvartsen, 2006). The incidence of fatty liver is strongly associated with the incidence of especially ketosis and displaced abomasum because these disorders are related to severe negative energy balance too (Bobe et al., 2004). Inhibition of gluconeogenesis may also occur when triglycerides accumulate in liver (Overton & Waldron, 2004) and additionally increase the risk for ketosis. Different aspects of the immune response are also suppressed in cows with fatty liver (Bobe et al., 2004; Overton & Waldron, 2004) and those animals are more prone to infectious diseases. However, the exact costs of fatty liver are difficult to estimate because condition can be diagnosed only by liver biopsy (Bobe et al., 2004).

2.2. Ketosis

Ketosis (acetonemia) is a metabolic disorder characterized by elevated concentrations of the ketone bodies (acetoacetate, beta-hydroxybutyrate and acetone), and a low to normal concentration of glucose in the blood. This disorder occurs both subclinically and clinically. Prevalence of subclinical ketosis is the highest in the first 2 weeks of lactation ranging from 8,9% to 34% in various studies (Ingvartsen, 2006; Rushen et al., 2008). Blood glucose in clinically affected cows fall below the level required to support nerve and brain function and cows often exhibit signs of central nervous system dysfunction. Ketotic cows also suffer inappetence which further exacerbates the negative energy balance. Milk production falls seriously which helps the cow to cope with the negative energy balance (Goff, 2006a).

Four main types of ketosis are: primary ketosis, secondary ketosis, butyric acid ketosis and underfeeding ketosis (Ingvartsen, 2006). Classical or primary ketosis (also called spontaneous or production ketosis) generally occurs in cows during the first 2 to 4 weeks of lactation (Goff, 2006a). It develops when the glucose demand exceeds the gluconeogenesis capacity of the liver resulting in increased ketogenesis, and thus in high concentrations of ketone bodies in blood, milk, and urine. The disorder is mainly seen in obese cows. Secondary ketosis results from another disease that depresses feed intake and increases body fat mobilization (Ingvartsen, 2006).

Butyric acid ketosis is caused by large amounts of butyrate in the feed and probably by related depressed feed intake. Silage with high butyrate concentrations results in an increased concentration of beta-hydroxybutyrate in the blood, and such silage is consumed in lower amount then normal one. Underfeeding ketosis occurs especially in cows that are fed insufficiently. Underfed animals are deficient in glucogenic precursors and this condition then leads to increased ketogenesis (Ingvartsen, 2006).

Another form of ketosis often seen in US dairies usually occurs in cows less than 10 days in lactation. It can often be difficult to treat as is generally accompanied by some degree of fatty liver (ketosis/fatty liver complex). Ketosis, like fatty liver, also occurs during periods of elevated plasma NEFA. Clinical symptoms are similar to classical ketosis, but ketotic state was actually preceded by an increase in fat accumulation in the liver (Goff, 2006a).

Major factors directly or indirectly increasing the risk of fatty liver and ketosis are: overconditioning at calving, excessive mobilization of body fat, low nutrient intake, some nutrient or diet specific factors and management and environmental stress (Ingvartsen, 2006). Ketosis is a metabolic condition that occurs primarily when a cow is in negative energy balance immediately after calving. To support the energy demands, the body mobilizes fat reserves. Excessive release of NEFA from fat depots may overwhelm the capacity of the liver to use the fatty acids as a fuel. They are instead converted to ketone bodies (Rushen et al., 2008). Feed intake is naturally depressed by about 20% around the time of calving. Simultaneous with the feed intake depression, plasma NEFA and liver triglyceride concentrations exhibited their greatest increase (Goff, 2006a). All factors exacerbating negative energy balance and depression of feed intake around calving increase the risk of ketosis, especially in overconditioned cows.

Negative energy balance, high blood levels of NEFA or beta-hydroxybutirate and ketosis reduce the response capacity of white blood cells so that invading bacteria can out compete the immune system of the cow (Zadoks, 2006). Hypoglycemia alone is not likely to exacerbate periparturient immunosuppression, but hyperketonemia appears to have multiple negative effects on immune functions (Overton & Waldron, 2004). Impaired immune functions around calving make cow more prone to infectious diseases. Cows that have suffered ketosis have a higher risk of ketosis in the following lactation (Ingvartsen, 2006). Affected animals produce 0,7-3,3 kg/day less milk in the rest of lactation (Fourichon et al., 1999) or about 200 kg annually (Guard, 1996). In addition, prolonged and pronounced negative energy balance in early lactation adversely affects reproductive performance of cows and increases the risk of other metabolic diseases (Rushen et al., 2008).

Ewes experience ketosis typically during the last month of pregnancy and is known as pregnancy toxemia (Schlumbohm & Harmeyer, 2003). Ovine pregnancy toxemia (twin lamb disease, pregnancy disease) occurs primarily in ewes carrying more than one fetus (Andrews et al., 1996; Schlumbohm & Harmeyer, 2003). It is usually seen when the plane of nutrition has been static or falling over the last month of gestation when the requirements of the ewe are increasing to allow the growth of the fetuses (Andrews et al., 1996). In goats, two clinical form of ketosis have been described: pregnancy toxemia during the last month of pregnancy and primary ketosis during the first month of lactation (Stelletta et al., 2008).

Limitation of the availability of glucose has been found to be a crucial factor for the development of pregnancy toxemia. Hyperketonemia lowered plasma glucose concentration and depressed endogenous glucose production in sheep by approximately 30%, and this facilitates the onset of pregnancy toxemia (Schlumbohm & Harmeyer, 2003).

Mortality is high if pregnancy toxemia is not treated, with only about 20% of affected ewes recovering without treatment. Encephalopathy can results from depressed glucose metabolism in the brain (Andrews et al., 1996).

2.3. Rumen acidosis

Ruminal acidosis is a nutritional disorder of ruminants generally resulting from ingestion of large amounts of feeds rich in readily fermentable carbohydrates, particularly when animals

have not been gradually acclimated to those feeds (Bramley et al., 2008). The disorder usually occurs in high-producing dairy cows. Subacute or subclinical ruminal acidosis (SARA) is considered to be one of the major threats to the welfare of lactating dairy cows and may affect up to 20% of cattle in early to mid lactation (Rushen et al., 2008). Subclinical rumen acidosis is defined as a condition where rumen fluid pH is below 6,0 while acute rumen acidosis is when rumen pH is below 5,5 associated with rumen motility that is weak or ceased (Ingvartsen, 2006).

Rumen acidosis classically occurs when an animal consumes the excess of grain (Stone, 2004). Fermentation of the high grain diet reduces rumen pH which can cause undesirable changes in microbial populations within the rumen (Goff, 2006a). Rumen pH is lowered due to large quantities of volatile fatty acids and lactic acid produced during grain fermentation (Bramley et al., 2008). Lactic acid production is not the hallmark of rumen acidosis in dairy cows, as observed in beef feedlot cattle. Instead, it is the total organic acid load induced by the high grain diet combined with the inability of the cow to buffer the acids with salivary secretions (Goff, 2006a; Stone, 2004). However, lactate accumulation may occur in cows after calving if the shift in fermentable carbohydrates between the diets fed before and after calving is too dramatic (Stone, 2004).

Low rumen pH can cause rumenitis, metabolic acidosis, lameness, hepatic abscesses formation, pneumonia, and even death (Bramley et al., 2008). Reduced ruminal efficiency, liver and lung abscesses, and laminitis all can be related to SARA (Stone, 2004).

2.4. Laminitis

Laminitis and laminitis-related hoof problems (sole ulcer, white line abscess, solar hemorrhage, etc.) are one of the leading causes of lameness in cows. Laminitis has been associated with nutrition, and specifically with ruminal acidosis either in its acute or subacute form. Exact relationship between laminitis and SARA is not known. One of the theories states that damage of the ruminal epithelium induced by acidosis allows absorption of histamine and endotoxins into the blood. These and possibly other compounds affect circulation within the hoof and cause inflammation leading to the condition known as laminitis (Stone, 2004). Cows fed the higher level of crude protein may have increased incidence and duration of lameness. It is considered that products of degradation of protein excess in the rumen may be the causative agents for lameness.

It is widely accepted that nutrition helps maintain claw health through the production of good quality horn (Baird & Muelling, 2009). For example, heifers fed on hay before calving might have better foot health than those fed silage, even if both groups are being fed the same diets postpartum. Forage type and level of moisture in the diet could influence lameness and this effect is exerted even before first calving (Logue & Offer, 2001).

It has also been shown that nutritional supplements such as biotin and zinc (Zn) can help reduce lameness through improving claw horn quality (Baird & Muelling, 2009; Goff, 2006a). Biotin is essential for two major metabolic pathways in keratinisation, keratin protein synthesis and lipogenesis. Other vitamins also may play important roles in

maintaining claw integrity, including vitamin A and vitamin E. Zinc, as a component of many enzyme systems, has a role in major functions during keratinisation including the formation of structural proteins (Baird & Muelling, 2009). This element improves claw integrity by speeding wound healing and epithelial tissue repair. Other trace minerals that impact claw condition include iodine (I), selenium (Se), copper (Cu), manganese (Mn) and Co. Calcium and phosphorus (P) are also needed for normal claw growth and integrity.

Laminitis reduces profitability of the dairy herd. It is estimated that 15% of cows culled for slaughter are culled due to laminitis. In clinically lame cows, milk yield was reduced from 4 months before and for the 5 months after treatment. The total mean estimated reduction in milk yield per lactation was approximately 360 kg (Green et al., 2002).

2.5. Displaced abomasum

Displaced abomasum is a multifactorial disease where the abomasum is dilated as a result of gas accumulation and dislocated to the left (left-displaced abomasum) or to the right (right-displaced abomasum) in the stomach in relation to the normal placing (Ingvartsen, 2006). The passage of feed to the intestines is partly or totally blocked. Approximately 80-90% of the incidences are left-displaced abomasums. The disease is most frequent in high producing cows in early lactation and 80–90% of the cases are seen in the first 4 weeks postpartum (Shaver, 1997). It occurs in approximately 3,5% of dairy cows each year (Goff, 2006a).

Nutrition has been implicated as a major risk factor in the etiology of displaced abomasums, but the precise cause is still unclear. Low feed intake and increased negative energy balance prepartum have been found to increase the risk of displaced abomasums in cows (Goff, 2006a; Ingvartsen, 2006). Cows fed high concentrate diets in early lactation or diets with inadequate particle size are also at increased risk of displaced abomasums (Goff, 2006a). Sudden changes in the diet and rapid increase in concentrate allowance in early lactation are also the risk factors. Some feeds increase the risk of the disease compared to others. Thus, a higher risk of displaced abomasum has been found for cows fed silage compared to those fed hay, probably because silage is often finely chopped. Risk can be almost eliminated if cow eats a kilogram of straw daily (Ingvartsen, 2006).

Displaced abomasum develops if three major conditions are met. The first one is reduced contractility and atony of abomasum which is gas-dilated. The next condition is that the mesentery shall stretch for the abomasum to be able to dislocate, and a third condition is the space in the abdominal cavity (Ingvartsen, 2006). The conditions leading to atony and reduced motility are still unclear, but hypocalcaemia around calving is a possible factor. Reduction in blood Ca concentration around calving results in a reduction of abomasal contractility, which can lead to its atony and dilatation (Shaver, 1997). Hypocalcemic cows after calving have 3,4 to 4,8 times increased risk of development of abomasal displacement (Massey et al., 1993).

Volatile fatty acids (VFA) in the abomasum also have been reported to reduce abomasal motility. Effects of VFA on motility may be exacerbated by low ruminal absorption of VFA

during the transition period (Shaver, 1997). Hypocalcaemia also may play a role in this process. Due to reduced feed consumption, slow contractions and inadequate filling of the rumen which therefore does not reach the ventral abdominal wall, empty space appears for movement of abomasum. Then usually more fatty acids escape absorption in the rumen and reach the abomasum. Those VFA, along with hypocalcaemia and accumulated gases, contribute to reducing abomasum contractility and development of atony (Goff & Horst, 1997c). Thus, inadequate feed consumption and insufficient rumen fill with reduced motility and strength of abomasal contractions together contribute to the onset of this disorder (Goff & Horst, 1997c).

Low intake of concentrates during the prepartum period also may increase the risk of left displaced abomasum because absorptive capacity of the ruminal papillae is not increased sufficiently and microbial population of the rumen is not adapted prior to intake of high energy postpartum diets (Shaver, 1997). Too rapid increase of concentrates after calving may reduce roughage intake and potentially increase the risk of displaced abomasum (Ingvartsen, 2006). Uncomplicated ketosis, fatty liver, retained placenta, and metritis are also risk factors for left displaced abomasums (Bobe et al., 2004; Shaver, 1997).

Treatment of displaced abomasum often requires surgical treatment, and deaths are not uncommon so that potential losses due to disease are very high. In addition, cows that recover from abomasal displacement produce about 350 kg less milk during the next month (Shaver, 1997) or 0,8-2,5 kg/day in the rest of lactation (Fourichon et al., 1999). According to Guard (1996) the average losses amounted to about 380 kg of milk annually.

2.6. Milk fat depression

Nutrition influences both the quantity and composition of milk fat. In modern dairy production cows are fed diets with high level of concentrates to maximize milk production but such diets often causes drop in milk fat. Condition is known as milk fat depression (MFD) or low-fat milk syndrome. Although milk volume and yield of other milk constituents may not be affected or may be even increased, depression of fat in milk can be a serious economic problem for dairy producers. This syndrome is not a disease, but rather metabolic consequence of attempts to reach the higher milk production in animals.

Milk fat depression refers to a marked reduction in milk fat yield with no change in milk yield or yield of other milk components (Harvatine et al., 2009). It represents a level of milk fat production below the genetic potential of the cow, usually as below 3,2% fat in milk for Holstein, or below 4,2% fat in the milk for a Jersey herd. When problem with MFD exists, the ratio of milk fat/milk protein will be less than 1,0 for Holstein herds. In severe cases the ratio will be less than 0,8. Milk fat yield can be reduced up to 50% and the effect is specific for milk fat (Bauman et al., 2008). The problem has been observed in many feeding situations and dietary conditions, including high level of concentrates and low level of dietary fiber, and diets supplemented with unsaturated oils. The fat content of milk can also be affected by the physical characteristics of the roughage, including grinding and pelleting (Perfield & Bauman, 2005). In diet-induced MFD, the yield of all individual fatty acids is

reduced, but the decline is greatest for short- and medium-chain fatty acids that are synthesized *de novo* in mammary gland (Bauman et al., 2008).

It is generally accepted that induction of MFD requires both an altered rumen environment and the presence of unsaturated fat in the rumen which biohydrogenation pathways are altered (Perfield & Bauman, 2005). Changes in ruminal microbial processes are an essential component for the development of MFD and are often associated with a decrease in rumen pH and a shift in the acetate/propionate ratio.

Historically, there have been several theories proposed to explain the basis for diet-induced MFD. The biohydrogenation theory was proposed by Bauman & Griinari (2001) focusing on the latest research in MFD problem. The authors suggested that "under certain dietary conditions the pathways of rumen biohydrogenation are altered to produce unique fatty acid intermediates which are potent inhibitors of milk fat synthesis". The theory was born after identification of *trans*-10,*cis*-12 conjugated linoleic acid (CLA) as a highly potent inhibitor of milk fat synthesis (Bauman & Griinari, 2001). This isomer is a rumen precursor of t*rans*-10 18:1 in biohydrogenation pathway that may arise under certain dietary conditions, including high concentrate/low fiber diets. The biohydrogenation of linoleic acid in rumen involves the formation of *trans*-11 18:1 and *cis*-9,*trans*-11 CLA as the main intermediates. However, under certain dietary situations the other pathways of biohydrogenation can happen and some of the intermediates produced during the process may be potent inhibitors of milk fat synthesis (Bauman & Griinari, 2001). The most extensively studied is *trans*-10,*cis*-12 CLA. Minimal quantities of this isomer markedly inhibited milk fat synthesis and a curvilinear reduction in milk fat yield occurred with increasing *trans*-10,*cis*-12 CLA in the rumen content (Baumgard et al., 2001).

Isomer *trans*-10,*cis*-12 CLA alone does not completely explain the extent of the decrease in milk fat. Additional biohydrogenation intermediates produced in the rumen probably inhibit milk fat synthesis and two of them (*trans*-9,*cis*-11 and *cis*-10,*trans*-12 CLA) have already been identified (Bauman et al., 2008).

Consequences of MFD are almost exclusively related to losses in yield of milk fat and lower price of milk. As problem is normally reversible, health consequences are usually not a matter of concern. However, MFD inducing diet is usually risky for rumen homeostasis due to high level of carbohydrates and low level of effective fiber which may reduce ruminal pH and cause acidosis (Bergen, 2009). If acidosis is not compensated and drop in ruminal pH is not prevented, the condition may become an important animal health issue.

2.7. Parturient hypocalcaemia

The lack of Ca in the diet does not lead to any changes in health or production for a long time because it is compensated by mobilization of Ca reserves in the skeleton. The change of Ca content in the blood may not occur until the cows show symptoms of osteoporosis and bone fractures. A unique example, however, is an acute hypocalcaemia in dairy cows that occurs in the periparturient period as a result of sudden loss of great amounts of Ca in

colostrum along with temporary dysfunction of the mechanisms of Ca mobilization from bones. From a relative inactivity in the dry period, these mechanisms often fail to achieve full activity quickly enough to maintain normocalcaemia around calving (Horst et al., 1994). More pronounced hypocalcaemia causes progressive neuromuscular dysfunction which is manifested as a specific clinical syndrome known as paresis puerperalis (milk fever, parturient paresis, calving paralysis). More often, however, and in a larger number of cows, hypocalcaemia exists in a subclinical form with very few or no symptoms (subclinical hypocalcaemia).

Hypocalcaemia was defined as the content of total Ca in blood below 2 mmol/L with or without clinical signs of paresis (Oetzel et al., 1988; Radostits et al., 2000), which is roughly equivalent to 1 mmol/L of ionized Ca (Massey et al., 1993; Oetzel, 1996).

Milk fever (MF) is non-febrile disease of adult dairy cows accompanied by general weakness, circulatory collapse and depression of sensation (Oetzel, 1988). It is one of the most common metabolic disorders in intensive dairy production (Horst, 1986) and a typical nutritional disorder (Ender et al., 1971). The disease attacks 5-10% of adult dairy cows in the U.S. and Europe annually, primarily those with high productivity. The classic syndrome of MF occurs immediately before or after parturition with about 87% of cases in the first 48 hours after calving and only about 9% cases before or during the parturition (Oetzel, 1988). The disease is characterized by pronounced hypocalcaemia which is accompanied by hypophosphataemia in most cases, and by more or less serious hypermagnesaemia (Phillippo et al., 1994).

Phenomena like paresis may rarely occur in beef cows, ewes (before or after lambing) and more frequently in dairy goats (Oetzel, 1988). In mares, the disease can occur several weeks after birth and is known as milk tetany or eclampsia (Radostits et al., 2000).

Milk fever has been recognized as a nutritional disorder with various endocrine abnormalities which occur more or less as a secondary phenomenon (Ender et al., 1971). The characteristic of the disease is an acute inability to mobilize Ca from bone (Horst, 1986) despite apparently normal endocrine dynamics in most affected cows (Radostits et al., 2000). The problem seems to lie in the reduced sensitivity of target tissues (bone, kidneys and intestines) on calcitropic hormones due to reduced number of receptors or because of their dysfunction (Horst et al., 1994).

Widely accepted theory for a long time was that MF was caused by a high content of Ca in the diet consumed before calving, as well as by unfavorable ratio of Ca/P. However, further studies emphasized importance of the high content of monovalent cations in the diet, mainly potassium (Block, 1984; Ender et al., 1971; Goff & Horst, 1997b; Horst & Goff, 1997). As a relative excess of cations in the diet affects blood acid-base balance toward alkalosis, the disruption of integrity of tissue receptors is related to metabolic alkalosis that normally exists in cows at the time of calving (Goff, 2000). Thus, the primary cause of MF is considered to be the temporary inability of cow tissues to adequately respond to stimuli generated by calcitropic hormones, mainly parathyroid hormone (PTH) (Goff et al., 1991; Goff, 2000).

In addition to monovalent ions, risk factors also include dietary magnesium (Sansom et al., 1983), dietary P (Curtis et al., 1984), and possibly vitamin D (Goff, 2000; Horst, 1986). Animal factors as the risks for hypocalcaemia include age (Curtis et al., 1984; Dishington, 1974) and breed (Goff, 2000; Oetzel, 1988). Adult cows are at increased risk for the disease. Occurrences are more frequent from the third lactation onwards, reaching the plateau of 12-15% in cows 6-10 years of age (Curtis et al., 1984; Dishington, 1974). The most predisposed breeds for milk fever are Jersey and Guernsey, followed by Holstein and Brown Swiss. In the case of Jerseys possible reasons are considered to be the higher milk production per unit of body weight (Oetzel, 1988) and a higher content of Ca in the colostrum (Goff, 2000). In addition, the number of receptors in the intestine is about 15% lower in Jerseys than in Holsteins (Goff, 2000; Horst et al., 1997).

Depending on the age, breed, feeding regimen and housing conditions, as many as 50-80% of cows can suffer MF annually in some herds (Oetzel, 1988). Concerning that well-timed treatment of MF easily solves the problem and is relatively inexpensive, the disease was not considered as a factor of economic importance in dairy production for a long time (Radostits et al., 2000). However, later findings confirmed its close relationship with other health disorders in the puerperium (Curtis et al., 1985; Massey et al., 1993). Many of these disorders are now considered as complications of hypocalcaemia. They generally occur as a complex, rarely as isolated diseases (Curtis et al., 1985) and include most of metabolic and reproductive disorders in periparturient period: dystocia, retained placenta, metritis, uterine prolapse, ketosis, mastitis and displaced abomasum (Horst et al., 1997). Risk of occurrence of each of them is much higher in hypocalcemic cows (Curtis et al., 1985). A well known physiological effect of hypocalcaemia is atony of smooth and skeletal muscles because their contractility is a function of Ca concentration in extracellular fluid (Ramberg et al., 1984). Most of the possible complications are related specifically to reduced contractility and to atony of smooth muscles of digestive and reproductive tract (Beede, 1995).

Spontaneous recovery of MF is usually not possible and approximately 75% of affected cows die if treatment fails (Oetzel, 1988). Even under normal conditions about 8% of treated cows still die due to various complications, 12% of them are culled (Guard, 1996) and about 25% require another treatment. Due to increased susceptibility to other health disorders and possible complications, the production life of cows that experienced MF was reduced by an average of 3-4 years (Horst et al., 1997).

Subclinical hypocalcaemia influences in the same manner as the clinic one, but to a lesser extent. As is more common in the herd, adverse effects of subclinical hypocalcaemia on herd economy can be equal or even greater than the effects of MF due to its broader influence on feed intake, secondary disease conditions, and milk production during early lactation (Horst et al., 1994).

2.8. Hypomagnesaemia

Magnesium is an essential mineral with many functions in the body but its homeostasis is not hormonally regulated. The concentration of Mg in the blood is dependent exclusively on

its absorption from the diet. If Mg secretion in milk and its endogenous losses exceeds absorption from the forestomachs hypomagnesaemia occurs because of the lack of hormonal control. Hypomagnesaemia is common problem in ruminants and may be one of the major health problems of cattle, sheep and goats in large scale production systems especially in temperate climates (Mayland, 1988; Stelletta et al., 2008).

Clinical hypomagnesaemia is also called hypomagnesemic tetany, grass tetany, spring tetany, or lactational tetany. Clinical signs usually occur when the animal is both hypomagnesaemic and hypocalcaemic (Robinson et al., 1989). In its subclinical form, however, hypomagnesaemia may be risk factor for other diseases. Around calving it may be the important risk factor for MF (Sansom et al., 1983; Schonewille et al., 2008).

Hypomagnesaemia may develop due to Mg deficiency in the diet or due to its low utilization in the gut. It may also occur because of a need for increased amounts of Mg during parturition and early lactation (Mayland, 1988). Clinical hypomagnesaemia in cows with plasma Mg concentrations bellow 0,4 mmol/L is manifested as grass tetany (Schonewille et al., 2008). Grass tetany has been investigated extensively, but its complex etiology is not well understood. Large number of factors influences the development of the disease (Robinson et al., 1989). It appears within 2-4 weeks after cattle or sheep have been turned out to rapidly growing pasture. Ewes with twins are more susceptible to grass tetany than are ewes with single lamb (Mayland, 1988). Specifically, older lactating animals consuming lush, intensively fertilized, cool-season grasses during the early spring are the most frequently affected (Robinson et al., 1989). Older animals also have reduced ability to mobilize body reserves of Mg. Lower average environmental temperatures (<14°C) facilitate the onset of the disorder (Mayland, 1988). However, periods of rapid plant growth during any season, resulting in forage of low Mg and high moisture, high nitrogen (N) and K, present dietary conditions that increase the potential for the development of tetany (Robinson et al., 1989). Grass tetany also may develop if animals graze forage that is high in digestible protein, but low in digestible energy (Mayland, 1988).

Grass tetany generally occurs when the dietary intake of total Mg is not particularly low, but factors which increase the animal's requirement for Mg or reduce the availability of dietary Mg are present (Mayland, 1988). The Mg concentrations in forage and subsequently in the blood of cattle are influenced strongly by high amounts of fertilizer K and, to some extent, fertilizer N. Absorption of Mg by plants is reduced by high levels of K in the soil (Mayland, 1988; Robinson et al., 1989). Mg absorption by ruminants is also reduced by a high intake of K (Schonewille et al., 2008), and by high content of Ca and P in the diet (Sansom et al., 1983). High concentrations of N in the forage may additionally decrease the availability of Mg (Mayland, 1988).

Absorption of Mg is dependent on the concentration of Mg in the rumen fluid and the functionality of the Mg active transport process across the rumen wall. The active transport mechanism is critical for the animal when dietary Mg concentration is less than 0,25%. Several factors, such as dietary K, can inhibit Mg absorption by this pathway. At high concentration of Mg in the rumen it will be absorbed by passive transport, and this

mechanism is not affected by high K but only by the solubility of Mg in the rumen fluid. This mechanism requires dietary Mg to be not less than 0,35% (Goff, 2006b).

Mg deficiency results in reduced appetite which decreases total nutrient intake (Robinson et al., 1989), thus chronic hypomagnesaemia results in reduced feed intake and milk production. It may progress quickly into acute hypomagnesaemia which terminates in convulsions, coma and death. One-third of animals with clinical symptoms die (Mayland, 1988). Even mild form of hypomagnesaemia (Mg <0,85 mmol/L) significantly reduces the mobilization of Ca from the skeleton around calving (Goff, 2000; Sansom et al., 1983). That is why hypomagnesaemia may be a risk factor for parturient hypocalcaemia and milk fever. According to Sansom et al. (1983) possible reasons for inhibition of Ca mobilization are considered to be:

a.   influence on PTH secretion; there are indications that serious Mg deficiency may impair or completely interrupt secretion of PTH,
b.   interference with the action of PTH on target tissues; the integrity of interaction between PTH and its receptors is disrupted and activity of initiated enzymes is disabled,
c.   interference with the metabolism of vitamin D; the first phase of vitamin D hydroxylation in the liver requires Mg^{2+} ions, while the second phase in the kidney takes place in the presence of PTH.

2.9. Udder edema

Udder edema occurs sporadically in cows and heifers near parturition, peaking in severity during the immediate prepartum period. Unless complicated, recovery of edema is spontaneous within a few days after calving. However, if edema is sufficiently severe it can interfere with suckling by the calf, milking, and may cause other complications including udder inflammation. Edema is caused by excessive accumulation of fluid underneath the skin and at least some mammary edema is associated with pregnancy and parturition, especially in primigravid heifers (Malven et al., 1983).

Investigations of the causes of udder edema and the development of strategies to reduce its prevalence have progressed in very limited degree during last several decades (Goff, 2006a). Some authors (Schmidt & Schultz, 1959) proposed that severity of udder edema is based on an inherent physiological phenomenon, because a cow may tends to have the same amount of edema each year regardless of the feeding. Feeding program had little if any effect on udder edema (Randalu et al., 1974). "Steaming up" method of feeding dry pregnant cows and high level of concentrates in their diet was initially blamed for high incidences of udder edema. However, investigation found that the amount of edema at calving was not related to grain feeding during the dry period or after calving (Schmidt & Schultz, 1959). Edema also is not correlated with the body condition of the cows (Schmidt & Schultz, 1959). However, addition of Na or K to the diet before calving can increase the incidence and severity of udder edema in dairy cows and first calf heifers (Nestor et al., 1988). In practical terms, high level of NaCl in the feed during the dry period may be one of the major factors in the development of udder edema around calving. Conflicting results from some earlier studies on effect of grain on

udder edema could be explained with salt content of the diets. However, KCl as a replacement for NaCl results in edema of about the same severity (Randalu et al., 1974).

Cows with severe edema that requires veterinary treatment are more likely to have additional health problems. Authors found higher culling rates for cows with more severe edema. Thus, there would be a substantial economic benefit to minimizing edema in dairy herds (Dentine & McDaniel, 1984).

2.10. Retained placenta

Inadequate antioxidant status or "oxidative stress" of the cow contributes to a poorly functioning immune system and increases the risk of mastitis as well as retained placenta (retained fetal membranes, placental retention). Fetal membranes are retained if not expulsed longer than 12 hours after parturition. Se and vitamin E are important dietary antioxidants and their low levels in the diet are associated with a high incidence of mastitis and retained fetal membranes (Goff, 2006a). Subsequently, addition of vitamin E or Se may improve antioxidant status and decrease the incidence of those diseases. The similar effects can be obtained by addition of beta-carotene in the diet. Blood lymphocyte proliferation was higher in cows supplemented with beta-carotene, and phagocytic activity of blood neutrophils was enhanced as well as intracellular killing by blood neutrophils. Therefore, dietary beta-carotene can elevate blood beta-carotene and enhance peripartum host defense mechanisms by enhancing lymphocyte and phagocyte function (Michal et al., 1994).

Hypocalcaemia, among others, may be an important risk factor in the development of retained placenta. Muscle weakening or absence of uterine contractions in hypocalcemic animals does not contribute to the expulsion of fetal membranes (Goff & Horst, 1997c; Oetzel, 1988). In cows with hypocalcaemia placental retention is 3,2 to 4 times more frequent than in normocalcemic cows (Curtis et al., 1985). Hypocalcaemia also delay the physiological involution of uterus and increases the incidence of metritis (Beede, 1995). Moreover, hypocalcaemia is considered as one of the main causes of uterine prolapse, also due to loss of uterine muscles tone.

Cows with retained placenta were 3 times more likely to develop mastitis than animals without retained placenta (Overton & Waldron, 2004). It has been reported that placental retention, metritis and mastitis predisposes dairy cows to foot problems. Moreover, uncomplicated ketosis, retained placenta, metritis, and hypocalcaemia at parturition are also risk factors for left displaced abomasums (Shaver, 1997). Cows with retained placenta or metritis produce 0,3-2,3 kg/day less milk during subsequent lactation (Fourichon et al., 1999). In the case of retention alone, Guard (1996) stated that losses are on average 350 kg of milk annually.

2.11. Metritis

Metritis and endometritis are inflammatory uterine diseases. They frequently occur soon after calving and may severely compromise reproductive performances. Metritis and

endometritis refer to the inflammation of the uterus and of its endometrial lining - both conditions are referred to subsequently as metritis (Urton et al., 2005). Younger cows were more likely to have dystocia or assisted deliveries, while older cows were most likely to have retained placenta and metritis (Lewis, 1997).

In some herds, up to 40% of the postpartum cows may be diagnosed with, and treated for uterine infections. However, the exact causes of uterine infections are unknown but are associated with several factors. Cows with dystocia, retained placenta, or stillbirths, and other metabolic disorders are more likely to develop metritis than healthy cows. Impaired immune functions before and after calving seem to predispose cows to severe uterine infections. It has been suggested that the function of neutrophils is impaired in cows that develop uterine infections. Thus, methods for regulating immune function in periparturient cows may have potential for preventing uterine infections. However, prevention of uterine infections is still difficult because the primary causes cannot be defined clearly (Lewis, 1997). Malnutrition influences the ability of the immune system to function, which affects the incidence of diseases such as mastitis and metritis (Goff, 2006a).

Cows suffering metritis exhibit reduced milk yield and reproductive performances (Urton et al., 2005). Few cows die from uterine infections, but affected animals are more likely to be culled for poor reproductive performances. The estimated cost to producers for each cow with metritis was 106 U.S. dollars (Lewis, 1997). Many of the financial costs of metritis are indirect, such as increased days open or predisposition to other diseases, and are thus difficult to measure. As mentioned previously, metritis is one of the diseases that predispose dairy cows to foot problems and left displaced abomasums (Shaver, 1997).

In contrast, the effects of metritis on milk production can be measured immediately, and losses during first four months after calving can be almost 270 kg. Also, besides reduced milk production in sick animals, some pharmaceuticals for treatment of uterine infections contaminate milk with residues, and the milk must be discarded. This is how uterine infections may have an indirect effect on milk production (Lewis, 1997).

3. Use of blood and milk analyses to evaluate nutritional and disease status

If recognition of subclinical diseases is difficult, the condition may be confirmed by analyzing blood, milk or sometimes urine, although some of them are still difficult to diagnose in practice, including rumen acidosis and fatty liver (Ingvartsen, 2006). Blood and milk analyses as tools to evaluate nutritional and disease status of individual animal or whole herd are aimed to help making decisions for improvement of nutritional strategies and production management. However, many problems are associated with interpretation of results of laboratory analyses, including Compton metabolic profile test, as well as other tools for assessment of metabolic status of dairy animals.

3.1. Milk analyses

Producers can use changes in milk production or in milk composition to monitor the health of their animals, but these tools are not always completely reliable because milk production corresponds poorly with mild or subclinical infectious disease. Nevertheless, measuring energy balance from changes in milk composition, most likely changes in milk fat and protein contents, could provide a cheap and reliable estimator of energy balance. A study clearly showed that there was a strong relationship between energy balance and milk composition under stable feeding conditions (Friggens et al., 2007). Milk composition varies with energy status and was proposed for measuring energy balance on-farm. Ratio milk fat/protein below 1,4 indicates the optimal or positive energy balance, and above it balance is negative (Pehrson, 1996; Zadoks, 2006). During peak lactation many cows with negative energy balance have this ratio in milk even above 2,1 (Pehrson, 1996).

The biological basis for the relationship between fat/protein ratio and energy status of the animal can be found in two physiological features: a) mechanism that maintains milk energy output by increasing milk fat content when yield is compromised due to a deficit in energy supply, and b) decreased milk protein content under negative energy balance (Friggens et al., 2007). Negative energy balance also may be reflected in elevated ketone bodies which are excreted in milk and urine. Milk has about half the ketone level of blood, and is recommended to check milk ketone levels for detection of ketosis.

Milk fat depression is an example of disorder that can be diagnosed exclusively by milk analysis. Specific blood test for MFD diagnosis does not exists, but milk analyses are usually enough to evaluate risk for or presence of MFD in a herd. Every drop in milk fat percentages with no changes in the content of other milk constituents and milk yield can be considered as MFD. In serious cases, diet-induced MFD can result in reduction of milk fat yield of up to 50% or even more (Bauman & Griinari, 2001; Bauman et al., 2008) and represents one of the greatest risks for production economy.

3.2. Blood analyses

Analyses of blood constituents have long been a matter of concern as a possible tool for assessment of diet adequacy or metabolic and health status of animals. Compton metabolic profile test (CMPT) originally involved the analysis of a set of blood variables from three groups of seven cows, one near peak lactation, and others in midlactation and in late dry period (Kronfeld et al., 1982). The samples are collected at least three times yearly: summer, autumn and winter, or when nutritional imbalance is expected, using the same procedures and timings (Radostits et al., 2000). Means of variables are calculated for each lactational group in each herd, and this set of means constitutes the metabolic profile. Each group mean is compared to reference ranges determined from corresponding means plus or minus two standard deviations that are based on group-means for all herds (Kronfeld et al., 1982). The test was based on the concept that laboratory measurement of certain components of the blood will reflect the nutritional status of an animal with or without presence of clinical abnormalities. However, the results of research indicate that CMPT may be useful only as an

aid in the diagnosis of the nutritional imbalances and production diseases. It must be carefully planed and is still expensive. Laboratories with automated analytical equipment should be available and this is often a major limiting factor (Radostits et al., 2000).

Compton metabolic profile test includes following analyses: blood glucose, packed cell volume, hemoglobin, blood urea nitrogen, serum inorganic phosphate, serum Ca, Mg, K and Na, total serum protein, albumin and globulins, serum Cu and iron (Fe), and plasma NEFA. Obtained results are interpreted with other relevant information taken on the day of sampling related to individual animals or to the herd: age, milk yield, days in milk, concentrates and forage intake, etc (Radostits et al., 2000).

Workers tested the CMPT as a guide to the nutritional status of dairy cows, and found that blood variables were not reliable predictors of energy and nutrients consumption relative to the requirements. Then they supposed that, for prediction of nutritional status, selection of blood variables should be probably different. Those workers have suggested, however, that protein intake may be reflected in blood concentrations of urea, albumin, and hemoglobin. Similarly, blood glucose concentration has attracted attention as an index of energy intake, although results from study to study have been inconsistent (Kronfeld et al., 1982).

Despite limitations and unconformity of metabolic profile tests, blood analyses still can help in diagnostics of some nutritional imbalances. Negative energy balance in postpartum cows can be detected by change in concentration of some blood metabolites (Rushen et al., 2008). As condition that affect immune functions and predispose animals to many metabolic disorders, it is important that negative energy balance is reflected in a higher levels of NEFA and beta-hydroxybutyric acid (BHBA) in the blood. To screen a herd for negative energy balance, Zadoks (2006) recommends having at least 12 animals tested. Testing of NEFA is done 2-14 days before calving and BHBA testing at 2-21 days after calving. If more than 10-15% of animals have NEFA levels above 0,40 mEq/L or BHBA levels above 1,36 mmol/L, the herd is considered to be suffering from excessive negative energy balance. Ketosis and fatty liver are diseases typically associated with negative energy balance for long periods of time. Increased ketone bodies and NEFA in the blood, and decreased blood glucose level are common findings in cows with ketosis and fatty liver. Values of glucose below 2,2 mmol/L are considered subnormal. However, fatty liver in cows currently can be diagnosed only by liver biopsy (Bobe et al., 2004).

The concentration of BHBA in the blood may be taken as a guide for correction of ration supplement for ewes during the final weeks of pregnancy to prevent pregnancy toxemia. It has been recommended to check 10% of the flock and feed is increased if blood concentration of BHBA exceeds 0,8 mmol/L (Morgante, 2004). Besides hypoglycemia and hyperketonaemia, plasma cortisol levels also may be elevated in sheep with pregnancy toxemia (Andrews et al., 1996). Early in the disease, both does and ewes will show a positive test for ketone bodies in the urine (Morgante, 2004).

There are no specific blood variables for detecting metabolic diseases like laminitis, displaced abomasums, udder edema, retained placenta and metritis. However, if these diseases are herd problems, blood metabolic profile should be checked for more than one

variable, and carefully used as an aid for development of preventive strategies. When laminitis is a problem, a metabolic profile on both dry and lactating cows as well as springing heifers should include both red and white blood cells count, packed cell volume, Se, Zn, Cu, Fe, blood urea nitrogen, vitamins A and E, and beta-carotene. When retained placenta is a herd problem, blood profile should include serum minerals, Se, vitamin E, and beta-carotene. In individual cases, blood urea nitrogen and packed cell volume should be included. Metritis requires testing metabolic profile on dry and fresh cows which should include white blood cells count, Se, Zn, Cu, Fe, Mg, blood urea nitrogen, vitamins A and E, and beta-carotene.

Use of blood analyses to evaluate degree of hypocalcaemia is sufficient diagnostic test for this disorder. Concentration of Ca may be determined in whole blood, but more often determination is performed in plasma or serum. When there are no disturbances in acid-base status and protein metabolism, ionized and total Ca are strongly correlated and therefore total Ca concentrations in plasma may serve as an acceptable diagnostic value (Oetzel, 1988).

Hypocalcaemia means that the content of total Ca in the blood is below 2 mmol/L, or below 1 mmol/L of ionized Ca (Massey et al., 1993; Oetzel, 1996). Signs of paresis can occur at total Ca level of 1,9 mmol/L, but most of the cows remain on their feet down to 1,0-1,25 mmol/L. A reduction in the plasma Ca concentration at parturition is usually accompanied by hypophosphataemia and hypermagnesaemia (Phillippo et al., 1994). However, this is not always the case, especially if hypocalcaemia is not severe and is not clinically manifested (Crnkic et al., 2010; Joyce et al., 1997; Oetzel et al., 1988).

Blood analysis is also sufficient diagnostic test for hypomagnesaemia. Based on blood serum or plasma Mg levels, animals may be normally magnesemic (0,74-1,23 mmol/L), chronically hypomagnesemic (0,20-0,74 mmol/L) or acutely hypomagnesemic (<0,20 mmol/L) (Mayland, 1988). Sampling and analysis of the blood of several cows within 12 hours after calving is a good indicator of Mg status of the periparturient period. If serum Mg concentrations are less than 0,82 mmol/L in 90% of cows it suggests insufficient dietary Mg absorption (Goff, 2006a).

4. Nutritional strategies to reduce metabolic diseases incidences

Although metabolic disorders are not easily categorized as to their cause, nutritional strategies have been developed to help prevent many of these disorders (Goff, 2006a). Scientific justification of those measures can be found in many research articles published in scientific journals during the last decades. However, problems in application of the strategies in the field still exist, as well as their limitations and possible negative consequences on milk production economy in certain circumstances. Strategies are based on major factors directly or indirectly increasing the risk of diseases such as overconditioning at calving, excessive mobilization of body fat, low nutrient intake, nutrient or diet specific factors and management and environmental stress (Ingvartsen, 2006). Strategies are expected to be able to reduce morbidity and at the same time improve reproduction and production.

To prevent metabolic disorders in the periparturient period nutritional strategies must start prior to calving. In a survey conducted by Curtis et al. (1985) consumption of nutrients before calving was directly related to the occurrence of metabolic disorders, and directly or indirectly to the occurrence of reproductive disorders after parturition. In most cases, these disorders occur as a complex and many of them are interrelated in their occurrence (Beede, 1995; Curtis et al., 1985). Consequently, strategies to reduce one disease can help preventing others. For example, strategies to reduce liver triglyceride accumulation at calving may decrease incidence of ketosis, etc.

Goff & Horst (1997c) recommended that three basic physiological functions must be maintained during the periparturient period if disease is to be avoided: adaptation of the rumen to lactation diets that are high in energy density, maintenance of a strong immune system, and maintenance of normocalcaemia. Whenever one or more of these functions are impaired, the incidence of both metabolic and infectious diseases is increased. However, measures to maintain these physiological functions must be conducted carefully avoiding other risk factors such as overconditionig and excessive mobilization of body fat around calving.

Metabolic disorders that may appear in the rest of lactation also require adequate prevention strategy to be controlled, including rumen acidosis, laminitis, hypomagnesaemia and milk fat depression.

4.1. Adaptation of the rumen

Fully adapting the rumen flora to a high starch diet that will be fed after parturition requires about 3 to 4 weeks, and full development of rumen papillae requires about 5 weeks of concentrate feeding (Goff & Horst, 1997c). It is, therefore, important to start increasing concentrates in the diet 3-4 weeks before calving and continue during the first 1-2 weeks after parturition to fully adapt rumen to lactation diet. If fresh cow is abruptly switched to a high starch lactation diet, the risk of developing rumen acidosis exists because the lactate production and accumulation. During the rest of lactation, the most reliable means of preventing rumen acidosis is to apply feeding methods that ensure a more even distribution of feed intake over the day. Feeding TMR only once or twice a day may result in that cows eat an excessive amount of feed during a short period of time, because cows are strongly attracted by the arrival of fresh food (Rushen et al., 2008). Buffering agents such as Na-bicarbonate or alkalinizing agents such as Mg-oxide are added to high concentrate ration to reduce the risk of acidosis (Goff, 2006a). Na-bicarbonate should be supplemented particularly to corn silage-based diets at the rate of approximately 0,8 to 1% of DM (Stone, 2004). Too rapid increase in concentrate allowance during early lactation may reduce roughage intake and increase the risk of not only rumen acidosis, but also displaced abomasums (Ingvartsen, 2006).

A highly significant relationship between forage neutral detergent fiber (NDF) content in the diet and ruminal pH has been found. NRC (2001) recommended 19% of forage NDF as absolute minimum when formulating rations in the field. A system of "physically effective"

NDF (peNDF) relates the ability of a feedstuff to stimulate chewing relative to a hypothetical long grass hay containing 100% NDF. The peNDF of a feed is the product of its physically effective fiber (pef) and NDF content. The diet should contain about 22% peNDF to maintain ruminal pH of 6,0 (Stone, 2004).

Gradual adjustment of the rumen to a high concentrate diet can help avoiding serious drop in feed intake around calving and minimize body fat mobilization in early lactation. The plasma NEFA concentration is negatively correlated with DMI and depression in feed intake around the time of calving was largely responsible for fatty liver development (Goff, 2006a). Therefore, all nutritional measures that prevent drop in DMI before parturition may be useful in prevention of fatty liver. However, it has been assumed that increased energy and nutrient density of the diet may assure maintenance of the same intake of nutrients and energy despite lower DMI around calving, and decrease rate of lipid mobilization. Increase in nutrient density during the last 2–3 weeks prepartum by increasing concentrates in the ration has been referred to as "steaming-up" or "close-up" diet (Ingvartsen, 2006). Use these diets should not last for too long because of risk of overfeeding energy and development of obesity. NRC (2001) recommends increasing the energy content of the precalving diet from 5,2 MJ/kg of DM during the "far-off" dry period, to 6,8 MJ/kg of DM for the 3 weeks before calving. This strategy is thought to prepare the cow for the metabolic demands of early lactation and thereby minimize the need for body tissue mobilization (Urton et al., 2005).

As fatty liver and ketosis in cows often occur as a complex, all measures to reduce fatty liver incidence may decrease incidence of ketosis (Grummer, 1993). Moreover, positive effects on ketosis incidence and lipid transport also have been seen when niacin or rumen-protected choline is fed to dry and fresh cows (Goff, 2006a). The treatment of pregnancy toxemia in ewes is usually unsuccessful, therefore the prevention is of key importance to reduce occurrence of the disease. Grain is a high source of available energy. Feeding 0,5-1 kg of grain daily along with high quality hay during the last four to six weeks of pregnancy will help prevent pregnancy toxemia.

Manipulation of the nutritional program of dairy cows affects rumen health, which influences hoof health (Stone, 2004). It is very evident that feeding diets that cause drop in rumen pH will result in increase in laminitis cases. To minimize the drop in rumen pH it is necessary to limit amount of concentrate fed per meal to no more than 3,6 kg and provide fresh feed at the bunk throughout the day. Diet should contain at least 25% total NDF or 19% acid detergent fiber (ADF), with non-fiber carbohydrate (NFC) levels between 35 and 40% or non-structural carbohydrate (NSC) levels between 30 to 35%, and minimize abrupt changes of ration. Adding buffers to diets may help maintain claw integrity as buffers, such as Na-bicarbonate, minimize the drop in rumen pH. Supplements that contain combinations of complexed trace minerals Zn, Mn, Cu and Co positivelly influence claw health, and it has been advised to feed them when lameness is problem in a herd.

Increased energy content of the diet fed during the prepartum period was also associated with decreased incidence of displaced abomasum (Curtis et al., 1985). Risk of displaced abomasum for cows fed silage can be almost eliminated if every cow eats a kilogram of straw daily (Ingvartsen, 2006).

4.2. Maintenance of immunity

Maintaining of a strong immune system may help to reduce incidence of infectious diseases after parturition including those related to nutritional factors: retained placenta, metritis, mastitis, laminitis, etc. Inadequate nutrition may contribute depression of the immune system that occurs around calving time (Rushen et al., 2008) when stress of parturition and metabolic challenges experienced by the dairy cow at the onset of milk production impair immune cell function (Goff, 2006a).

Dietary factor that may influence immune functions include vitamin E and Se as the most important vitamin and mineral related to immunity. To a lesser extent vitamin A and beta-carotene, Cu and Zn may play a role (Zadoks, 2006). Metabolic conditions related to parturition also may exacerbate immunosuppression, including negative energy balance (Zadoks, 2006), hypocalcaemia (Ganjkhanlou et al., 2010), and hyperketonemia (Overton & Waldron, 2004). Therefore, strategies to maintain strong immune system must include feeding adequate or increased levels of all dietary components that influence immunity, as well as prevention of metabolic disorders that may exacerbate immunosuppression.

Most measures explained in the preceding section related to adaptation of the rumen to lactation diets may help maintain immune functions throughout reduction in negative energy balance and hyperketonemia. Measures to reduce hypocalcaemia around calving are presented in the following section. Feeding vitamin E and Se have long been associated with reducing incidences of retained placentas and uterine infections. Increased protein content of the diet fed during the prepartum period was also associated with decreased incidences of retained placenta (Curtis et al., 1985).

Although feeding is generally not related to the incidence and severity of udder edema, some dietary measures can help prevention of the problem. Restriction of the salt NaCl in the diet reduces the severity of udder edema (Randalu et al., 1974). Restriction or exclusion of other Na or K sources from the diet is also recommended until the levels of dietary Na and K are not in line with dietary recommendations. NRC (2001) recommends at least 0,1% Na in dietary DM for close-up dry cow diet and at least 1% K. As membrane permeability may be a primary cause of udder edema, vitamin E supplementation precalving may be a supportive preventive measure (Thomas et al., 1990). More recently, feeding anionic diets or diets with additional antioxidants have shown some promise in reducing udder edema (Goff, 2006a). Prevention of udder edema is important as condition has temporary effects of pain and stress for the cow, and may increase risk of udder inflammation and additional health problems.

4.3. Prevention of parturient hypocalcaemia

Concerning effects of hypocalcaemia on many physiological functions it is obvious that health, production and reproduction can be compromised in hypocalcemic cows even in the absence of clinical signs of paresis (Oetzel, 1996). Therefore, measures to prevent decline of blood Ca in cows after calving can improve milk production in herds that apparently have

no problem with this disease. Prevention aims to increase the mobilization of Ca from the skeleton, or its absorption in the gastrointestinal tract, or both. The most important nutritional measures for prevention of hypocalcaemia include manipulation of minerals in the diet which is nutritionally balanced in accordance with requirements of the cows several weeks before calving. This method of prevention is based on limiting the consumption of Ca or increasing the content of anions in the diet.

4.3.1. Anionic diet

An anionic, or acidic, diet is one supplemented with anionic salts to provide more anions (Cl^- and S^{2-}) relative to the cations (Na^+ and K^+). It has a negative dietary cation-anion difference (DCAD), calculated as mEq/kg of DM = (Na + K) – (Cl + S). It is well known that anionic diets help maintain blood Ca at parturition and prevent milk fever when fed to cows during the last several weeks of pregnancy (Block, 1984). Feeding an anionic diet before parturition has been advised if the incidence of milk fever in a herd exceeds 10%, and also when it is desired to improve the health status and production in herds in which MF is not a serious problem (Horst et al., 1994; Oetzel, 1993).

Diet with excess of anions, mainly Cl- and S^{2-}, relative to the cations Na^+ and K^+ acidifies the body and is therefore considered as acidogenic (Goff & Horst, 1997b). The two PTH-dependent functions, including bone resorption and production of 1,25-$(OH)_2$D, were enhanced after feeding acidogenic diet which contributes to lower incidence of hypocalcaemia after calving (Goff, 2000). However, the diets of dry cows in the field are always more or less alkalogenic and have a positive DCAD. When feeding diets with positive DCAD the acid-base balance tends to metabolic alkalosis, and vice versa. Formulation of acidogenic diet is only possible by supplementation with chloride and sulfate in a quantity that provides a relative excess of Cl- and S^{2-} in the diet. Manipulation of dietary cations and anions, however, is limited by metabolic requirements and by tolerance levels of minerals in the diet.

The literature offered a dozen different formulas to calculate DCAD, which include some or all dietary minerals with or without the use of coefficients related to their utilization from the diet or the degree of influence on acid-base status:

A. (Na+K) – (Cl+S)   Ender et al. (1971)
B. (Na+K) – (Cl+S+P)   Lomba et al. (1978)
C. (Na+K) – Cl   Gaynor et al. (1989)
D. (Na+K+Ca+0,3P) – (Cl+S)   Goff et al. (1991)
E. (Na+K+0,38Ca+0,3Mg) – (Cl+0,6S+0,5P)   Goff (1992)
F. (Na+K+0,38Ca+,25P+0,3Mg) – (Cl-0,6S)   Goff (1992)
G. (Na+K+0,38Ca+0,3Mg) – (Cl-0,6S)   Horst et al. (1997)
H. (Na+K+0,15Ca+0,15Mg) – (Cl+0,2S+0,3P)   Oetzel (2000)
I. (Na+K+0,15Ca+0,15Mg) – (Cl+0,25S+0,5P)   Goff (2000)
J. (Na+K) − (Cl+0,6S)   Goff et al. (2004)

Equations A, B, and C imply the complete absorption of each dietary element that can be considered accurate only in the case of equation C. Equations E and G take into account the coefficients of utilization of those elements that are not completely utilized. Equations H and I could be considered biologically and functionally most accurate because they include the degree of influence of individual ions on acid-base status, and are physiologically the most relevant (Horst & Goff, 1997; Goff, 2000).

Equation F can be used to assess the risk of developing MF. All the elements that increase the risk of MF are on the left side, while those who decrease the risk are on the right side of equation. Equation D can serve the same purpose (Goff et al., 1991). The last equation J, (Na + K) − (Cl + 0,6S), was the most recently proposed by Goff et al. (2004).

Oetzel (1991) collected data from 75 published experiments and determined the risk factors of diet in the development of MF using meta-analysis technique. Comparing the three different equations to calculate DCAD he found that the equation (Na + K) - (Cl + S) was strongly correlated with the appearance of MF. The author in the same study well justified the inclusion of S in the calculation of DCAD. Charbonneau et al. (2006) used the same technique but found that the equation (Na + K) − (Cl + 0,6S) was the most highly associated with clinical milk fever (R^2 = 0,44) and urinary pH (R^2 = 0,85).

Element	A_r	Valence	Equivalent weight (g/Eq)	Conversion factor (from % in mEq/kg)
Na	22,99	1	22,99	434,98
K	39,09	1	39,09	255,77
Ca	40,08	2	20,04	499,00
Mg	24,31	2	12,16	822,88
Cl	35,45	1	35,45	282,06
S	32,06	2	16,03	623,83
P	30,97	3	10,32	968,56

Table 1. Mineral elements in the diet used for calculation of DCAD

Mineral content in feed is usually expressed as a percentage so it is necessary to convert it in mEq/kg for calculation of DCAD. Equivalent weight (g/Eq) of each element is calculated by dividing the relative atomic weight (Ar) with its valence. For example, Ar of S is 32,06. Dividing 32,06 by 2 we get the equivalent weight of S which is 16,03 g/Eq. Factor for conversion of percentage in mEq/kg is calculated by dividing the 10.000 with equivalent weight of the element. For S it is 10.000/16,03 = 623,83 (Table 1). Multiplying this factor with percentage of the element in dietary DM its content is expressed in mEq/kg DM. When this is calculated for each element in the equation, then the sum of cations is subtracted from the sum of anions and DCAD value is obtained. The example of calculating DCAD of alfalfa hay and rapeseed meal using equation (Na + K) - (Cl + S) is given in Table 2.

Alfalfa hay	K	Na	Cl	S
Content in DM, %	1,71	0,12	0,38	0,28
Factor for multiplication (F)	255,77	434,98	282,06	623,83
Content in mEq/kg DM (% × F)	437,37	52,20	107,18	174,67
DCAD mEq/kg DM [(Na+K) – (Cl+S)]	489,57 – 281,85 = + 207,72			
Rapeseed meal				
Content in DM, %	1,36	0,10	0,11	1,25
Factor for multiplication (F)	255,77	434,98	282,06	623,83
Content in mEq/kg DM (% × F)	347,85	43,50	31,03	779,79
DCAD mEq/kg DM [(Na+K) – (Cl+S)]	391,35 – 810,82 = - 419,47			

Table 2. Example of calculating DCAD in alfalfa hay and rapeseed meal

The example in Table 2 clearly shows the difference in the alkali-acid production potential of the two feeds depending on their mineral content. A positive DCAD of alfalfa hay is result of the relatively high K content. Extremely negative DCAD of rapeseed meal is result of high S content.

Most diets commonly used for dry cows have DCAD value of +100 to +250 mEq/kg DM (Oetzel, 2000) and even up to +500 mEq/kg DM (Pehrson et al., 1999). By choosing appropriate feeds DCAD can be reduced, but not sufficiently to influence Ca metabolism. It is therefore necessary to enrich the diet with Cl and S by adding anionic salts in a quantity that provides a negative DCAD. That is, indeed, a standard diet that contains all essential nutrients required by dry cow and was further enriched with sources of Cl and S in amount that causes a mild metabolic acidosis.

Acidogenic, or anionic mineral salts are chlorides and sulfates with a high content of Cl and S, not containing Na and K. Alkalogenic salts are, on the other hand, Na and K salts that contain organic anion which is metabolized and are also called cationic salts (Na_2CO_3, $NaHCO_3$, K_2CO_3, $KHCO_3$, etc). They have the effect opposite to anionic salts and are undesirable in the diet of dry cows.

To formulate an anionic diet three chlorides and three sulfates are commonly used (Table 3). Two or more of them are usually added depending on mineral content of the diet. Ca and Mg salts also serve to meet requirements in these two minerals whose content in anionic diet should be higher than in standard diet (NRC, 2001). Ammonium salts, besides Cl and S, are also a source of non-protein nitrogen.

Acid production potential or acidifying activity of certain salt depends on preferential absorption of anions in relation to cations which the salt is consisted of (Goff et al., 1991). Phosphates, for example, have a weak acidifying activity as they are absorbed only slightly better than the corresponding cations (Horst et al., 1997). NaCl is neutral salt as both elements are absorbed completely and none is metabolized, so it does not affect neither DCAD nor acid-base status.

Salt	M_r	Val	g/Eq	DM, %	% of DM					DCAD
					Ca	Mg	N	Cl	S	mEq/kg DM
$MgSO_4 \times 7H_2O$ [1]	246,51	2	123,26	48,83		20,20			26,63	-16.613
$MgCl_2 \times 6H_2O$ [2]	203,33	2	101,67	46,83		25,53		74,46		-21.002
$CaSO_4 \times 2H_2O$ [3]	172,18	2	86,09	79,07	29,44				23,55	-14.691
$CaCl_2 \times 2H_2O$ [4]	147,02	2	73,51	75,49	36,11			63,88		-18.018
$(NH_4)_2SO_4$ [5]	132,14	2	66,07	100,0			21,20		24,26	-15.134
NH_4Cl [6]	53,49	1	53,49	100,0			26,19	66,27		-18.692

[1]magnesium sulfate heptahydrate (Epsom salt), [2]magnesium chloride hexahydrate, [3]calcium sulfate dihydrate (gypsum), [4]calcium chloride dihydrate, [5]ammonium sulfate, [6]amonium chloride, M_r – relative molecular weight of a substance (sum of atomic weights of all atoms in the molecule), Val – valence, g/Eq – equivalent weight (M_r/valence of cation), DCAD = (Na+K) – (Cl+S).

Table 3. Characteristics and chemical composition of anionic salts

Anionic salts are not harmless substances and require caution for the use and handling them. The main limiting factors are bitter and salty taste and potential toxicity of higher doses. NH_4Cl is considered the most toxic, followed by $CaCl_2$. The combination of salts is the best solution because it reduces the possibility of harmful effects (Oetzel, 2000). The most acceptable method of administration is mixing salts in the feed.

An alternative to the anionic salts is adding mineral acids directly into a diet. Very potent in causing systemic acidosis is hydrochloric acid (HCl), while sulfuric acid (H_2SO_4) is less efficient (Goff & Horst, 1997a). An additional advantage of mineral acids is that cows prefer diets with acidic taste rather than bitter-salty taste of anionic salts. Goff & Horst (1998) found that efficient prevention of MF can be achieved with only 1,5 Eq of HCl in the diet, and that with no adverse consequences up to 2,5 Eq of the acid can be fed daily. Moreover, the addition of HCl in the diet had, unlike anionic salts, a beneficial effect on the consumption of feed. For safety, it is not advisable to use pure acid or keep it on farm, but rather as commercial products in the form of acidified feeds where the acid is mixed with some feed as a carrier. Byproducts of fermentation are usually used for this purpose, and also soybean meal or sugar beet pulp (Goff & Horst, 1997a, 1998).

Feeding anionic diet few weeks before calving significantly reduces the incidences of MF and subclinical hypocalcaemia in the herd, and improves milk production and reproductive performances of cows in the subsequent lactation (Beede et al., 1991; Block, 1984; DeGroot et al., 2010). Metabolic acidosis caused by anionic diet is subclinical, mild and compensated, and with no significant impact on animal health, but may influence some physiological functions if lasts long enough. Increased sensitivity of PTH receptors in renal tissue contributes to increased production of 1,25-$(OH)_2$D before parturition (Gaynor et al., 1989; Goff et al., 1991). Cows fed anionic diet have a higher content of 1,25-$(OH)_2$D in plasma, although changes in secretion of PTH does not occur (Phillippo et al., 1994). The active form of vitamin D takes part in osteolysis with PTH (Horst et al., 1994; Horst, 1986) and stimulates Ca reabsorption in renal tubules (Goff, 1992). Since 1,25-$(OH)_2$D is important for the functioning of both Ca compensation mechanisms, change in its secretion is considered as an important effect of anionic diet.

Oetzel (1993) recommended the application of anionic salts in the herds with high incidence of MF (>10%) if not possible to formulate low Ca diet, or to improve production and reproduction in the herd which apparently does not have high incidence of MF. Adding anions in the diet is, therefore, to be considered not only for preventing MF, but also for prevention of subclinical hypocalcaemia which is responsible for the frequent occurrence of other metabolic and reproductive disorders in puerperium (Horst et al., 1994). Beede (1992) states that even in well-kept herds, where cows are in proper condition with no major problems with metabolic disorders, an additional 250-500 kg of milk can be achieved by using anionic salts in diets before parturition probably because lower incidence of subclinical hypocalcaemia.

Based on results of earlier studies, Horst et al. (1997) found that the most effective diets for prevention of MF are those with DCAD from -50 to -100 mEq/kg DM, while others state that it is between -50 and -150 (Beede, 1995), or -200 (Horst et al., 1994). However, Beede et al. (1991) achieved a good preventive effect with DCAD -250 mEq/kg, and Goff et al. (1991) with -230 mEq/kg. Too low DCAD, irrespective of the amount of added salts, can reduce feed consumption because too strong metabolic acidosis which depresses the appetite in animals (Goff & Horst, 1997b). Preventive effect of anionic diet on MF incidence occurs only if DCAD is below -40 mEq/kg DM in most cases, regardless of the type and quantity of added salts.

A risk for many health and reproductive disorders in puerperium is increased in cows with hypocalcaemia (Curtis et al., 1985; Massey et al., 1993). The prevention of hypocalcaemia can, in addition to better health status of cows in puerperium, improve milk production and increase reproduction performances in the herd (Beede et al., 1991; Block, 1984; DeGroot et al., 2010). Comparing the milk production in healthy cows with those who suffered MF, Block (1984) found greater milk production by about 14% in healthy animals. The same author found that cows fed anionic diet in the dry period produced on average 486 kg (7,3%) more milk than those fed cationic diet. Beede et al. (1991) conducted a field experiment with 510 cows and showed three positive effects of anionic diet: enhanced Ca metabolism in periparturient period, increased milk production in subsequent lactation, and better reproductive performances. Cows fed anionic diet before parturition produced 327 kg more milk (about 3,6%) than control cows.

Because of unpleasant taste, anionic salts can have depressing effect on feed intake (Joyce et al., 1997; Vagnoni & Oetzel, 1998), but this is minimal if salts are properly used (Block, 1984; Moore et al., 2000; Oetzel et al., 1988). Up to 300 mEq of anions/kg DM (3-3,5 Eq of salts per day per cow) can be added to the diet without depressing effect on feed intake (Horst et al., 1994; Oetzel, 2000). Intake also could be influenced by the type of salt because more acidic salts have less favorable taste. Feed intake depression was at least expressed with $MgSO_4$, and much more with other salts, mainly $CaCl_2$ and NH_4Cl (Oetzel & Barmore, 1993). Last two also have much higher acidifying activity in relation to $MgSO_4$.

The best and easiest method of application of anionic salts is mixing in TMR which effectively masks their taste. In the conventional feeding system application of anionic salts is difficult, but still possible. The salts should be manually mixed in silage or haylage, or in concentrates (Oetzel & Barmore, 1993). In the latter case, salts should be mixed in sufficient amount of concentrates containing palatable feeds, at least 2,3-2,6 kg (Oetzel & Barmore, 1993; Pehrson et al., 1999).

Oetzel (2000) finds that preventive effect of anionic salts can be achieved if cows consume anionic diet at least 5 days before calving, while others state that at least 10 days is necessary. Since the expected and actual date of calving are matter of discrepancies in practice, it is advisable to start feeding salts 3-4 weeks before expected parturition, at least 2-3 weeks, to ensure that most of the cows consume the diet at least 10 days (Beede 1992, 1995).

NRC (2001) gives fairly broad recommendations for the content of Ca in anionic diet for dry cows, from 0,6 to 1,5% DM, which is not difficult to formulate when anionic Ca salts are used. Anionic salts should not be fed if Ca intake is below 50 g/day (Oetzel, 1993). As hypomagnesaemia negatively affects Ca metabolism at the time of calving, many authors emphasize the importance of adequate content of Mg in dry cow diet (Sansom et al., 1983; Thilsing-Hansen et al., 2002). Recommendation has increased from earlier 0,20-0,25% to the current 0,35-0,40% DM either in standard or in anionic diet (NRC, 2001). Increasing dietary Mg up to 0,40% DM has no negative consequences so, even if not prove useful, poses no risk or any practical problem in the formulation of a diet when anionic Mg salts are used (Wang & Beede, 1992). On the other hand, the Mg level of 0,4% DM has been also set as the maximum tolerable (NRC, 2001).

If we assume that DCAD in efficient anionic diet should be around -100 mEq/kg DM, it means that the initial DCAD should not be greater than +200 to +250 (Horst et al., 1997). Therefore, the diet must be formulated using feeds with lower content of K, such as corn silage, grass hay, etc. If necessary, part of the forage with high content of K can be replaced with concentrates rich in fiber, such as brewers' grains, sugar beet pulp, malt sprouts, etc. The most common problem is grass silage and alfalfa silage because they can contain more than 3% K. Most cereal grains have almost neutral DCAD, while it is more negative only in rapeseed meal and brewers grains primarily due to high content of S (NRC, 2001).

In field conditions, a marked decrease in feed intake may occur when anionic salts are included in the diet for the first time, therefore, adjusting cows should last at least three days (Oetzel, 2000)

The most accurate biological indicator of the degree of acidification of the body is pH of urine (Vagnoni & Oetzel, 1998). Urinary pH in cows was decreased linearly with decreasing DCAD (Charbonneau et al., 2006; Ganjkhanlou et al., 2010). The optimum pH of urine to prevent puerperal hypocalcaemia in Holsteins fed anionic diet is 6 - 6,5 (Horst & Goff, 1997) or wider, 6 - 7 (Moore et al., 2000). In Jersey cows, however, the pH of urine is necessary to reduce to 5,8 - 6,2. If the pH is lower than the specified, amount of anionic salts should be reduced and vice versa.
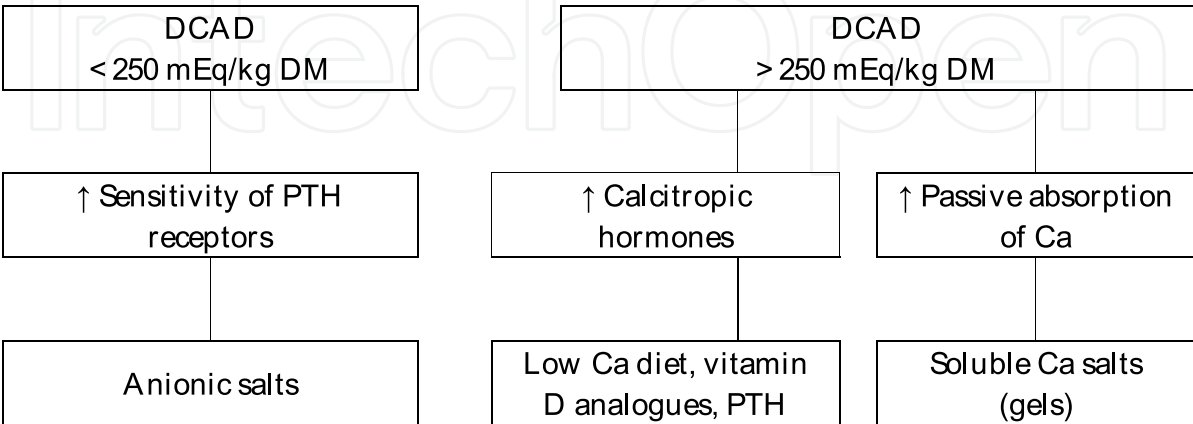
4.3.2. Low calcium diet

Maintenance requirements of the cow and requirements of fetus during high pregnancy are usually satisfied with 35-45 g Ca/day (NRC, 2001). The content of Ca in the diet is often beyond that, and the requirements in this case are met mainly by passive absorption, while mechanisms of mobilization of body reserves and active absorption of Ca in the intestine are suppressed. Inactivity of these mechanisms in the dry period makes cows difficult to adapt to the sudden loss of Ca in colostrum at the moment of mammary gland activation. A few days required for starting these mechanisms causes temporary crisis in Ca homeostasis that results in decline of Ca in the blood (Goff, 1992).

When Ca content in the diet is below the minimum requirement, the animal is dependent on Ca mobilization from bone with simultaneous increase of active Ca absorption in the gut (Horst, 1986). These mechanisms can be activated before parturition and maintained active by constant stimulation up to the critical moment of parturition. Restriction of Ca intake to below 20 g/day caused negative balance of Ca and stimulates the secretion of PTH which increases tubular Ca reabsorption, bone resorption and production of 1,25-$(OH)_2$D (Goff, 1992; Horst et al., 1997). This allows the cow to use Ca more efficiently from the diet and from body reserves immediately after calving (Goff, 1992). Introduction of low Ca diet leads to a slight decrease of Ca and P concentrations in plasma which returns to the base level in 3-4 days due to simultaneous increase in secretion of PTH that remained increased up to calving time (Goings et al., 1974). Prolonged exposure of the tissues to elevated PTH levels after feeding low Ca diet can overcome tissue resistance to PTH that might be induced by high dietary K (Goff, 2006a). This is the way to reduce or avoid period of adaptation to sudden losses of Ca which usually takes several days (Goff, 1992). Rations formulated to contain less than 20 grams of Ca proved to be very effective in preventing MF and significantly reduce the occurrence of hypocalcaemia too (Goings et al., 1971, 1974; Wiggers et al., 1975). For the best effect, restrictions of Ca consumption in the dry period should last at last 7-10 days (Goings et al., 1974; Wiggers et al., 1975) and be folowed by a high Ca diet immediately after calving (Horst et al., 1994; Oetzel, 2000). Cows fed in this way at the moment of calving mobilize about 10 g of Ca from the skeleton daily that is enough to prevent the occurrence of MF (Wiggers et al., 1975). Increasing Ca in the diet above daily needs and manipulation of its content within these limits does not affect the blood Ca status if other dietary minerals are maintained unchanged (Goff & Horst, 1997b).

Feeding low Ca diet to dry cows is considered the traditional way of preventing MF. For this reason, the use of feeds rich in Ca is usually avoided and the diet is formulated with corn silage and grass hay. Consumption of Ca can be reduced to 50-60 g/day in this way what often gives good results in the field (Goff, 1992; Horst et al., 1997). However, significant stimulation of parathyroid gland and complete preventive effect can be achieved only if Ca consumption is restricted to below 20 g/day. The formulation of such diet is, unfortunately, unrealistic in practice and that is the reason for its limited application (Goff, 1992). This type of diet has no adverse effects on production in the subsequent lactation (Goings et al., 1974), but the problem is, in addition to impracticality, that it may not last longer than 2-3 weeks because negative balance of Ca can be too exhausting for body reserves (Van Saun & Sniffen, 1996).

In the strategy for prevention of MF, Horst et al. (1997) recommended measures depending on the baseline cation-anion difference of the diet (Fig. 1). If it is less than 250 mEq/kg DM, the use of chloride and sulfate is justified without danger of low feed intake. If this value is above 250 mEq/kg DM it is necessary to consider other preventive measures, such as low Ca diet, short-term administration of oral Ca salts or some pharmacologic therapy (vitamin D analogs and active metabolites, PTH injections, etc.).

DCAD < 250 mEq/kg DM		DCAD > 250 mEq/kg DM	
↑ Sensitivity of PTH receptors		↑ Calcitropic hormones	↑ Passive absorption of Ca
Anionic salts		Low Ca diet, vitamin D analogues, PTH	Soluble Ca salts (gels)

Figure 1. Strategy for preventing milk fever (adapted from Horst et al., 1997)

Thilsing-Hansen et al. (2002) rewieved research conducted over the past 50 years and concluded that any measures for preventing MF, even if used under ideal conditions, rarely reach preventive effect of 100%. The same authors calculated that efficiency of low Ca diets is best, reaching 80-100%, and anionic diets efficiency was 65-80%.

4.4. Prevention of hypomagnesaemia

Commonly used parameter to characterize the grass tetany potential of forage is the ratio [K/(Ca+Mg)] (Mayland, 1988). Forages containing less than 0,2% Mg and a "tetany ratio" [K/(Ca+Mg)] greater than 2,2 have increased risk of inducing grass tetany (Crawford et al., 1998). The fertilizers containing N and K are the most important factors increasing [K/(Ca+Mg)] ratio in forages. Key step in nutritional prevention of hypomagnesaemia is finding a forage with lower ratio [K/(Ca+Mg)], or modify this ratio in the diet by adding more Ca and Mg supplements. Commercial grade MgO, $MgCl_2$, $MgCO_3$ and $MgSO_4$ are good sources. As hypomagnesaemia may induce hypocalcaemia, including Ca in supplements to prevent Mg tetany may have a beneficial effect (Robinson et al., 1989).

NRC (2001) recommends Mg level of 0,35-0,40% DM in the diet for dry cows, although studies showed no benefit from increasing dietary Mg above 0.2% DM when diets contain less than 3% K (Wang & Beede, 1992). Van Saun & Sniffen (1996) recommended increasing dietary Mg above 0,20% when the content of K exceeds 1,2 to 1,5% DM. However, Goff (2006a) recommends that Mg content of the close-up dry cow ration and the early lactation ration should be between 0,35 and 0,40% as insurance against the possibility that the active transport processes for Mg absorption are impaired. In pregnant cows high Ca intake decreased utilization of dietary Mg and increases its excretion in urine (Sansom et al., 1983)

that can be even worsened in metabolic acidosis (Wang & Beede, 1992). So it seems logical to increase Mg content in anionic close-up diet because it usually contains more Ca.

4.5. Prevention of milk fat depression

As milk fat depression has been observed over a wide range of feeding situations, this problem on dairy farms remains one of the more challenging tasks within overall nutritional management of dairy cows. Diets high in concentrates and low in fiber, and diets supplemented with plant or fish oil are the most often associated with MFD, but many other dietary factors also can affect milk fat synthesis including those which are able to alter rumen environment and those related to supply of polyunsaturated fatty acids (PUFA). Factors that can alter rumen environment include low level of physically effective NDF, feed particle size, total fiber in the diet, starch and non-structural carbohydrates, feeding pattern etc. On the other side, factors related to supply of PUFA are variation in fat content and fatty acid composition of feed ingredients, amount and availability of PUFA, and also feeding pattern.

Factor that alter rumen environment are first to consider in nutritional strategy to prevent or solve the problem of MFD, and those who affect rumen pH are the most important. Lower then normal ruminal pH, even without signs of acidosis, causes the change in bacterial population favoring those that have alternative pathways of biohydrogenation of dietary fatty acids. Inclusion of adequate level of so-called ''effective fiber'' and appropriate buffers in lactation diets can prevent drop in ruminal pH and markedly decrease MFD (Bergen, 2009). Forages, including long stemmed hay, are the main sources of effective fiber, thus the best method to maintain an adequate fat percentage in milk is to feed a balanced ration with adequate forage. The low levels of effective fiber may result from overfeeding of concentrates or the lack of forage, from consumption of large amounts of lush pasture and from silage or haylage that is too finely chopped (Perfield & Bauman, 2005).

Additional management practices to maintain a stable milk fat percentage in dairy herds include regular feeding of diet without abrupt changes, as well as feeding buffers such as Na-bicarbonate and/or Mg-oxide. Buffers are particularly useful when more than 5,5 kg of concentrate is fed per feeding and when frequent changes in diet are made.

Adding different sources of fat in dairy cow rations is a practice which has been favored when it is necessary to increase the energy consumption. However, higher amounts of fat can inhibit the activity of rumen bacteria and reduce the efficiency of fiber digestion, thus leading to a reduction in milk fat content (Schroeder et al., 2004). Although unsaturated vegetable oils can have a number of positive effects on fatty acid composition of milk fat, a negative effect on fat content must not be neglected due to the fact that the fat in milk is one of the main determinants of the price of milk and profits that farmers make. High levels of unsaturated oil in the diet can reduce fat content in milk along with possibly other adverse effects on production performances, such as drop in milk yield, decreased protein content in milk, low feed intake, etc. (Shingfield et al., 2006). Loor et al. (2002) found that the upper limit for dietary supplementation of unsaturated vegetable oils is 3,5% DM without serious nefative consequences on production. If fish oil is the supplement, it is at most 1% DM (Donovan et al., 2000).

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