



## Assessing the effect of nutrition on milk composition of dairy cows: A review

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### Abstract

The main objective of this study was to investigate the effects of nutrition on the milk composition of dairy cows used in the commercial pasture and supplement based dairy enterprises. Most dairy farmers tend to give more attention to the overall milk yield in their dairy cows and pay less attention to the overall milk components of a their dairy herd. However, consumers and dairy product producing companies that buy milk from dairy farms are more interested in milk components than milk yield. Hence, milk of dairy farmers known to produce milk that has high percentage of components such as fat and protein tend to be more profitable in markets than milk with low percentage of these components. Milk quality problems of the overall dairy herd of a farm are more likely affected by nutrition which is in turn affects milk composition. Therefore, poor knowledge of the relationship between dairy cow nutrition and milk components results in production of low quality milk with low milk.

**Keywords:** milk; nutrition; protein; energy; feeding; concentrates

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### Introduction

Milk of dairy cows is composed of water, proteins, fats, lactose, minerals and other dissolved components (vitamins and white blood cells). It can be noted that about 87.7% of milk is water, in which all other constituents are distributed in various forms (Closa, 2004). However, the main focus of this study is on fat and protein content of milk. The percentage of each component varies from one breed to another, but generally milk is composed of 87.7 %; protein 3.3%; fats

3.4%; lactose 4.9%; mineral salts 0.7%. The main driving forces for manipulating milk composition in dairy cows are the same now as they were 25 years ago; aimed at improving the manufacturing and processing of milk and dairy products, changing the nutritional value of milk to conform to the dietary guidelines, and using milk as a delivery nutraceuticals with known benefits to human health (Haug et al., 2007). The period from 1980 to 2005 has seen different efforts at trying to change the milk content or composition of all the three components

(i.e. fat, protein and lactose) (Mansbridge and Blake, 1997). The advance in altering milk composition by dietary manipulation come from significant contributions of the entire animal system, from practical studies on feeding systems to basic cellular work on mammary tissue metabolism (Bauman et al., 2003).

Feeding management practices on the dairy farm can have a major impact on the levels of milk fat and protein concentration in milk. Nutritional strategies that optimize rumen function also maximize milk production and milk components. However, there are several strategies that producers can use to enhance rumen function and the resulting milk components. For example, farmers that use information from their dairy records can more critically evaluate their nutrition and feeding management programs (Mansbridge and Blake, 1997). Utilization of herd and individual cow records allows identification of groups of animals, lactation, number of days in milk and economic assessment of these groups that contribute to declination in income when milk protein and or milk fat is reduced in the whole herd (Mansbridge and Blake, 1997).

Nutritional strategies that impact on milk components include adequate rumen degradable rumen protein and adequate feeding of forage neutral detergent fiber (NDF) in the diet especially for cows in early lactation. The impact of nutrition and nutritional changes in the ration can readily alter fat concentration and protein concentration. Fat concentration is most sensitive to dietary changes and can vary over a range of nearly 3.0 percentage units (Grainger and Goddard, 2007). Dietary manipulation in milk protein result in milk protein concentration approximately 0.60 percentage units (Jelen and Lutz, 1998). The concentration of lactose

and minerals, which are other solids constituents of milk, do not respond predictably to adjustments in diet. There are also many non-nutritional factors that can affect milk composition such as genetics and environment, level of milk production, stage of lactation, diseases, season, cow comfort, facilities and age of the cow (Jenkins, 1998).

#### **Nutritional factors and feeding practices**

All the factors affecting milk composition, nutrition and feeding management are most likely to cause problems (Jenkins, 1998). Milk fat depression can be alleviated within seven to 21 days by changing the diet of the cow. Milk protein changes may take 3 to 6 weeks or longer if the problem has been going on for a long period (Grainger and Goddard, 2007). Nutrition or ration formulation changes are strongly correlated to milk fat than milk protein. Nutrition and feeding management are considered the best solutions to a milk fat or protein problem other than genetics (Bequette et al., 1998).

#### **Source of milk components**

Digestion of fiber in the rumen produces the volatile fatty acids (VFAs) acetate and butyrate. Butyrate provides energy for the rumen wall, and much of it is converted to beta-hydroxybutyrate in the rumen wall tissue. About half of the fat in milk is synthesized in the udder from acetate and beta hydroxybutyrate (Dixon et al., 2001). The other half of the milk fat is transported from the pool of fatty acids circulating in the blood. These can originate from body fat mobilization, absorption from diet, or from fat metabolized in the liver. Rumen microbes convert dietary protein into microbial protein, which is a primary source of essential amino acids for the cow. These amino acids are absorbed by the mammary gland and used to synthesize milk proteins. Glucose is required to provide energy to support this

protein synthesis (Casper and Schingoethe, 1989). Glucose is either formed from VFAs propionate in the liver, or absorbed directly from the rumen, the cow will have to break down amino acids and convert them to glucose (a process called gluconeogenesis); this can reduce the supply of amino acids available to make milk protein. In addition, some albumin and immunoglobulin protein is transferred directly to milk from the blood (DePeters et al., 1992).

### **Feeding management**

Any situation that causes cows to eat abnormally or limits feed intake may affect milk components. Examples include: overcrowding at feed bunks, housing heifers with older cows in facilities at or near full capacity (Mentink and Cook, 2006). Feeding rations that encourage sorting and feeding infrequently in a conventional system (non-TMR) and also failing to push feed up or feed total mixed ration (TMR) enough change milk components. Feeding protein feeds before energy feeds and feeding grain before forage in non-TMR systems, all such feeding management practices change the dairy cow's milk components. These conditions can create slug feeding (one or two meals per day versus 10 to 15) or allow cows to eat high grain meals part of the time and high forage meals the remainder of the day. Ensure that fresh feed is available 20 hours each day, spoiled feed must be removed from the bunks, and shade or cooling must be provided during hot weather to help maintain normal intake and normal meal patterns. Finally, make ration changes gradually to allow rumen microorganisms time to adapt. Any reduction in the rumen microbial protein production from nutrition or feeding management imbalances will reduce milk protein by less of microbial protein for the cow to digest and

depress fat by limiting volatile fatty acid production in the rumen (Emery, 1978).

### **Maximizing feed intake**

The importance of maximizing feed intake is related to minimizing negative energy balance during early lactation (Dixon and Ernst, 2001). As dairy cows move into positive energy balance, body weight is regained, loss of body condition is minimized, and cows produce milk of normal fat and protein composition (Bequette et al., 1998). Increased feed intake can improve milk protein by 0.2 to 0.3 percentage units. This increased milk protein percentage may be due to overall increases in balanced energy intake as total feed intake increases. High producing dairy cows should eat 3.6 to 4.0 percent of their body weight daily as dry matter. If a dairy herd is consuming less dry matter than 3.6 to 4.0 percent of body weight, production of milk fat and protein components may be limited. Hence, increased feeding frequency increases milk fat and protein component, especially with low fiber, high grain diets (Peticlerc et al., 2000). The greatest response is seen in diets with less than 45 percent forage and when grain is fed separately, as in parlor feeding (Ouweltjes et al., 2007). When diets are fed as total mixed rations, feeding frequency is not as important as long as feed remains palatable and is fed at least once daily.

### **Energy effects**

In general, as energy intake or ration density increase and fiber decreases, milk fat content will be reduced, while protein content is increased (Jenkins, 1998). In contrast, as ration fiber levels increase and energy is reduced, milk protein is depressed and milk fat is increased. Lack of energy intake or lower energy digestibility may reduce milk protein by 0.1 to 0.4%.

This reduction may result from underfeeding concentrates, low forage intake, poor quality forage, and failure to balance the ration for protein and minerals, or inadequately ground or prepared grains. Shifting rumen fermentation so that more propionic acid is produced is apt to increase milk protein and decrease fat content (Bauman and Griinari, 2003). However, excessive energy intake, such as overfeeding concentrates, may reduce milk fat content and increase milk protein. Normal protein levels can be expected when energy needs are being met for most of the cows (Bequette et al., 1998). Often this is impossible to achieve with high producing animals.

#### **Fiber effects**

According to DePeters and Cant (1992), both fiber level and particle size contribute to the effectiveness of a fiber source for stimulating rumination (cud chewing) and salivation and maintain optimal milk protein and fat composition. Minimum acid detergent fiber (ADF) levels required in the of ration dry matter are 19 to 21 percent. Neutral detergent fiber (NDF) should not fall below 26 to 28 percent. Below these levels, cows risk a low milk fat test, acidosis, lameness, chronic feed intake fluctuations, and poor body condition (especially in early lactation). In order to assure adequate particle length, forage should not be chopped to less than 8 centimeters. Chopping finer than this may dramatically decrease fat percent and increase milk protein by 0.2 to 0.3 percentage units. However, while this practice might seem advantageous, but when over feeding non-fiber carbohydrates (starchy concentrates), even though milk protein and fat content increases, the cow and her rumen may become unhealthy (Brucknermaier et al., 2004). Feeding inadequate fiber is not recommended for increasing milk protein content

(Mansbridge and Blake, 1997). Preferably, 75 percent of the neutral detergent in a diet should come from long or coarsely-chopped forage to fully satisfy the cow's fiber requirement. Rations too high in fiber (too low in energy) limit milk protein production because not enough energy is consumed. Generally, 40 to 50 percent forage dry matter in a ration is the minimum amount necessary to avoid low milk fat test. When feeding 65 percent or more forage, it must be of high quality to avoid energy deficiencies which also lower milk protein (Emery, 1978).

#### **Protein effects**

Protein tends to be overfed in rations either deliberately through ration formulation or due to inadequate monitoring of feed management practices. However, a deficiency of crude protein in the ration may depress protein in milk. Marginal deficiency could result in reduction of 0.0 to 0.2 %, while more severe restriction of diet crude protein would have greater impact (Neitz and Robertson, 1991). Feeding excessive dietary protein does not increase milk protein content, as most of the excess protein is excreted. Dietary protein has little effect on milk fat levels within normal ranges. Dietary protein type also could affect milk protein levels (Casper and Schingoethe, 1989). Use of non-protein nitrogen (NPN) compounds, like urea, as protein substitute will reduce milk protein content by 0.1 to 0.3% if the NPN is the main provider of crude protein equivalent. Rations higher than recommended in soluble protein may lower milk protein by 0.1 to 0.2 %. Non-protein nitrogen levels in milk will be increased by excessive protein or NPN intake, heavy feeding of ensiled forages, ensiled grains, immature pasture and lack of rumen undegradable protein in the diet. The

rations for crude protein, rumen undegradable protein, and soluble protein must be balanced for better milk protein content. For high producing cows, balancing for amino acid also may be essential (Bequette et al., 1998). Protein nutrition is challenging because there are various nitrogen fractions, especially with ensiled feeds that add complexity when formulating rations and balancing them with carbohydrates. Excess protein fed results in increased nitrogen excretion (Jenkins et al., 1998). However, it is also an animal concern as excess nitrogen feeding reduces nitrogen efficiency and thereby impacts on milk components.

### **Concentrate intake**

Proper feeding concentrates primarily involves maintaining proper forage to concentrate ratios and non-fiber carbohydrate (NFC) levels (Cant et al., 1991). Non-fiber carbohydrates include starch, sugars, and pectin. According to Gabriella et al (2005), non-fiber carbohydrates should range between 20 to 45%. A level of 40 to 45% is typical of diets with forage to concentrate ratios of 40 to 60 or less forage. Diets with large amounts of high quality forage and minimal grain may be deficient in non-fiber carbohydrate. Feeding proper non-fiber carbohydrate levels can improve both milk fat and protein content. However, overfeeding concentrates result to milk fat depression of one or more percentage units and often increases milk protein by 0.2 to 0.3% units (Berner, 1993). An increase in the intake of concentrates causes a decrease in fiber digestion and acetic acid production. This creates an increase of propionic acid production. Propionic acid production encourages a fattening metabolism that is in opposition to milk fat. Addition of buffers to some rations may help to prevent acidosis (Nyman et al., 2009); this will not

change milk protein, but will increase milk fat content. Animals that eat a substantial amount of concentrates or a low ratio of dietary forage to concentrate may develop acidosis even when buffers are added to the ration. The non-fiber carbohydrate (NFC) portion of the diet is highly digestible and can influence both fat and protein content in milk (Gabriella et al., 2005). Excessive amounts of NFC can depress fiber digestibility, which reduces the production of acetate and leads to low milk fat (Emery, 1978). At the same time, greater propionate production allows higher milk protein levels of 0.2 to 0.3 percent. Generally non-fiber carbohydrate of 32 to 38% of ration dry matter is recommended to optimize production of milk fat and protein.

### **Grain processing effects**

According to Kononoff (2006), grain intake should be limited to a maximum of 10 to 15 kg per cow daily. Manure which contains undigested corn or with pH less than 6.0 indicates that too much grain, or non-fiber carbohydrates, is being improperly (Vasupen et al., 2006). Grain processing also influences milk composition. Feeding flaked corn increases milk protein content. Expect oats decreases milk protein by 0.2 percent compared to barley. Processed grain by cracking, rolling, grinding, or possibly steam-flaking enhances rumen starch digestion, which improves milk protein percentage. Pelleting also has similar effect. However, processed grain causes acidosis more easily than whole or very coarse-textured grains. Generally, rolled or ground barely or flaked corn causes a rapid and severe decrease in milk fat when overfed (Bauman and Griinari, 2003). Fibrous byproducts, such as soybean hulls, can replace a portion of starchy grains and reduce the severity of milk fat depression.

### **Forage level and physical form**

Balance rations for lactating cows to contain at least 40 to 45 percent of ration dry matter from forage. This may be changed by the level of corn silage in the ration and the level of high fiber by-product feeds in the ration. Low forage intake can cause a major reduction in the fat content of milk due to low fiber levels (Mentin and Cook, 2006). Several potential reasons for low forage intake are inadequate forage feeding, poor quality forage, and low neutral detergent fiber (NDF) content in forage that was cut at a very immature stage or late in the fall stage (Bauman and Griinari, 2003). Target a forage NDF intake of 0.9% of body weight daily. Although low forage diets increase milk protein production, this strategy is not recommended. The low forage levels contribute to acidosis and laminitis; they do not promote good health for the rumen or the cow in a long run. Protein and fat content also can be changed due to the physical form of forage being fed. Much of this is related to ration sorting and failure to provide a consistent diet throughout the day. Coarsely chopped silage and dry hay are the most common causes of sorting. At the extreme, very finely ground diets negatively affect rumen metabolism and depress fat and protein production. Monitoring ration particle size to ensure that adequate effective fiber must be provided and total mixed rations (TMRs) must be mixed properly and distributed evenly to all cows (Dixon and Ernst, 2001). Forage quality can severely impact the amount of energy cows are being provided in a ration. Therefore, in addition to doing forage test when new forages are harvested and fed consider having the laboratory to do digestibility measure of the forage as well. It can provide additional information that might shed light on whether lowered

milk fat is due to highly fermentable carbohydrates in the ration or inadequate energy provided to the cows stemming from low forage quality. Improvements in nitrogen efficiency impacts milk components.

### **Added fat or oil and extremely high milk fat**

Adding fat to the diet can affect milk fat component levels depending on the amount and source of fat (DePeters and Cant, 1992). Fat is generally toxic to rumen microbes and may reduce fiber digestibility when fat from natural resources exceeds 5% of ration dry matter. If rumen inert or by-pass fat is used, total fat content may safely reach 6 to 7%. At low levels of dietary fat, milk fat content could increase slightly or show no change at all (Gabriella et al., 2005). Milk fat is reduced at higher levels, especially with polyunsaturated oils. If fat or oil is rancid, milk fat content decreases even at low levels of consumption. Milk protein content may be decreased by 0.1 to 0.3% in high fat diets (Gabriella et al., 2005). This may occur due to reduced blood glucose levels.

High milk fat content often occurs in herds that are off feed and may have ketosis problems. Percent fat may be reduced for sick animals, but total fat may be higher for the herd. This may occur in herds fed large amounts of good quality forage combined with moderate concentrate levels. Producing an abnormally high level of fat is not economically feasible, because it usually indicates that total milk production is low (Bailey et al., 2005). Herds that depend primarily on milk income would be better served to increase total milk yield and keep fat percentage somewhat below the attainable maximum. Herds with unusually high milk fat are encouraged to reduce forage intake if it is on the high side, increase concentrate feeding, and manage the

nutrition of dry and transition cows more closely to control problems with low intakes and ketosis (Mansbridge and Blake, 1997).

### Conclusion

It is concluded that the nutrition affect the quality of milk and even the quantity. Although nutrition is thought to affect quantity of milk yield produced, this study revealed that nutrition also has effects on milk components. Any nutritional changes in a the overall animal diet at any time should be properly rehearsed and evaluated for their effects on milk components of dairy cows in both a short run and long run in dairy production.

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