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Review on Effect of Nutrition on Milk Composition and Yield of Dairy Cows

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Abstract. Nutrition affects the quality of milk and even the quantity. Nutrition is the single factor having the greatest influence on milk production performance of dairy animals. Milk composition is a trait of animal species, which cannot be altered under normal production systems. Changes in composition are attributed through the altered genetic makeup and by the dietary modifications. Feeding proper non-fiber carbohydrate levels can improve both milk fat and protein content. Protein and fat content also can be changed due to the physical form of forage being fed. The milk fat being the greater sensitive to dietary manipulation than other milk constituents has received a great attention of nutritional control of milk fat content and fatty acid composition. The nutritional factors that are having major influence on milk protein content are forage-to-concentrate ratio, the amount and source of dietary protein, and the amount and source of dietary fat. Any situation that causes cows to eat abnormally or limits feed intake may affect milk components. The nutrient density of diet and availability of desired in satisfying nutrient to support higher milk production are responsible in enhancing milk production of dairy animals.

Key words: Dairy cow, Milk Composition, Milk Yield, Nutrition

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).

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 major deriving forces for manipulating the composition of milk included the aims of improving the manufacturing and processing of milk and dairy products, altering the nutritional value of milk to conform the dietary specifications and using milk as a delivery system for nutraceuticals with known benefits to human health.

The most sensitive component of milk to dietary manipulation was fat content, which could be changed over a range of 3 percentage units (Ranjan *et al.*, 2013). The principal fatty acids of the milk are uninfluenced by the composition of the diet, the digestive system and by the biosynthesis process of milk within the animal. It is shown that the lactose content could not be manipulated by dietary changes, except under extreme and unusual feeding situations.

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. As in any livestock production system nutrition plays a vital role in allowing animal’s to produce to their maximum potential. Proper nutrition is vital for maximizing milk yield and Production in dairy cattle production systems.

Nutritional recommendations for a 454 kg cow, producing 10 kg of milk a day in mid lactation, is to have a total of 12.4 kg of dry matter intake with diet crude protein level of 12.6 %, 10% in rumen digestible protein (NRC, 2001). Thus objective is to review effect of nutrition on milk yield and milk composition of dairy cow.

Literature Review

Milk Production Performance

The nutrition affects the quality of milk and even the quantity. Although nutrition is thought to affect quantity of milk yield produced, that nutrition also has effects on milk components (Tyasi, Gxasheka, & Tlabela, 2015). Nutrition is the single factor having the greatest influence on milk production performance of dairy animals. The diets providing essential nutrient in appropriate and adequate quality and quantity promoted milk production.

Fat supplements are added in the diet of high producing dairy animals for increasing energy density without effecting fiber level (Tripathi, 2014).

Oilseeds and whole cottonseed are commonly used as primary dietary fat sources, that also providing protein and fiber. Proportion of unsaturated fatty acids in total fat has additional benefits; a high proportion increased the total and intestinal digestibility of fatty acids (Amorocho, Jenkins, & Staples, 2009).

The nutrient density of diet and availability of desired in satisfying nutrient to support higher milk production are responsible in enhancing milk production of dairy animals (Kass *et al.*, 2012).

Table 1. Milk composition of cows

Animal	Production level (kg/d)	Milk constituent			Reference
		Fat (g/kg)	Protein (g/kg)	Lactose (g/kg)	
Cow	High (>28)	40.2	29.5-30.5	44.8-45.3	Van Zijderveld *et al.* (2011)
		32.4-34	27.9-28.9	49.4-49.9	Pan *et al.* (2014)
	Medium (16-28)	19.3	39.3	32.6	Staerf *et al.* (2012)
		45.3-46.7	36-37.6	47.5-48	Kass *et al.* (2012)
	Low (<16)	41.7	33.3	48.2	Staerf *et al.* (2012)
		37.3-37.8	33.2-34.6	51.6-53.2	Santra *et al.* (2013)

Source: cited by Tripathi (2014)

Milk Composition

Milk composition is a trait of animal species, which cannot be altered under normal production systems. Changes in composition are attributed through the altered genetic makeup and by the dietary modifications. Nutrition has direct and impact on milk composition. Level of milk production also has some influence on milk constituents (Tripathi, 2014). Nutrition research of dairy animals broadened the opportunities altering milk composition through dietary manipulations. Dietary sources of nitrogen as urea or nitrate does not alter milk composition, yield of milk constituents and milk

Piper betle leaf feeding at 100 g per day in cows improved milk production and contents of fat, protein and lactose (Santra *et al.*, 2013). The modification of the basal diet of animals, especially by lipid supplementation, is the most appropriate procedure for modifying the milk fatty acid profile. The increasing amount of fats and oils in the feed of ruminant animals reduce food consumption and alter the rumen microorganism, resulting in a decrease in the production of milk and, some occasions, its protein content.

Maximize Feed Intake

The importance of maximizing feed intake is related to minimizing negative energy balance during early lactation. As 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 increased feed intake can improve milk protein by .2 to .3 percentage unit. 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 percent of their body weight daily as dry matter (Schroeder, 2012).

Example: 1,350-pound cow x .04 (4 percent) = 54 pounds of dry-matter intake If the diet is 55 percent dry matter, the cow should eat 98 pounds of feed as fed (54 ÷ 55 = 98).

If a herd is consuming less dry matter than 3.5 to 4 percent of body weight, production of milk solid components may be limited. 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 (Schroeder, 2012).

Effect of Grain Feeding and Forage

Concentrate Ratio on Milk Composition

Proper feeding of concentrates primarily involves maintaining proper forage-to-Concentrate ratios and non-fiber carbohydrate (NFC) levels (Schroeder, 2012). Non-fiber carbohydrates include starch, sugars and pectin. The level is calculated as: NFC = 100 – (crude protein + neutral detergent fiber + fat + minerals).

Non-fiber carbohydrates should range between 20 and 45 percent. A level of 40 to 45 percent 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 carbohydrates. Feeding proper non fiber carbohydrate levels can improve milk fat and protein test, while overfeeding leads to milk fat depression of one unit (.1) or more and often increases milk protein by .2 to .3 percentage unit (Schroeder, 2012).

Grain should be limited to 7 pounds per feeding to avoid rumen acidosis, off-feed problems and reduced fat content of milk. Grains processing also can influence milk composition. Feeding flaked corn has been shown to increase the milk protein percentage. Expect oats to decrease milk protein percentage by .2 units, compared with barley.

According to Gabriella, Varga, and Virginia (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 (Tyasi, Gxasheka, & Tlabela, 2015). Grain feeding typically reduces the proportions of milk fatty acids having 6 to 16 carbons, and increases the proportion of 18-carbon unsaturated fatty acids.

Therefore grain alone is responsible for milk fat depression, while mixed diets promoted the production of milk and milk protein. Reducing the proportion of forage in the diet of a cow increases both protein content and yield. Milk protein content can be increased by 0.4 percentage units or more if forage proportion in the diet is reduced to 10% or less of the diet DM. A minimum concentration (40%) of forage is needed in dairy diets to avoid digestive and metabolic disturbances. Reducing the forage-to-concentrate ratio has not been a practical method of consistently enhancing milk protein content.

Grain Processing Effects

According to Kononoff *et al.* (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 (Tyasi, Gxasheka, & Tlabela, 2015).

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 & Griinari, 2003). Fibrous byproducts, such as soybean hulls, can replace a portion of starchy grains and reduce the severity of milk fat depression (Tyasi, Gxasheka, & Tlabela, 2015).

Forage Level and Physical Form

Balance rations for lactating cows to contain at least 40 to 45% of ration dry matter from forage. This may be altered by the level of corn silage in the ration and the level of high-fiber by-product feeds in the ration (Tyasi, Gxasheka, & Tlabela, 2015). Low forage intake can cause a major reduction in the fat content of milk due to low fiber levels (Mentin & 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 too young or late in the fall. Target a forage NDF intake of 0.9% of bodyweight daily. Although low forage (high energy) 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 the long run (Tyasi, Gxasheka, & Tlabela, 2015).

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 other extreme, very finely ground diets negatively affect rumen metabolism and depress fat and protein production (Tyasi, Gxasheka, & Tlabela, 2015).

Milk Fat and Fatty Acids

The milk fat being the greater sensitive to dietary manipulation than other milk constituents has received a great attention of nutritional control of milk fat content and fatty acid composition. However, diet and fermentation pattern are implicated as the source of variations in milk fatty acids within an animal species.

Animal products are the main source of saturated fat and cholesterol. While, in majority of dairy production systems the pricing system for milk offered to producers was the premium for high fat content during past, which continuing until now, whereas many consumers are focused on low-fat dairy products that conformed to healthy dietary guidelines.

The conflict between consumer and producer over fat content generated interests of manipulating properties of milk fat by the enhanced the concentration of fatty acids having beneficial health effects in humans, which is usually to increase one or more unsaturated fatty acids in milk. The ability of different diet formulations to reduce milk fat content or enhance the concentration of unsaturated fatty acids directed by several dietary factors including the amounts of grain and fat fed to dairy animal.

Influence of fat supplements on the control of milk fat and fatty acid composition is complex because the transfer of dietary unsaturated fatty acids to milk can be reduced several factors including their destruction by ruminal microorganisms, poor rates of intestinal absorption, and their deposition in mammary fat and secretion in milk.

Table 2. Effect of diet type on milk production and composition

Diet type	Diet specialty	Milk yield	Milk composition	References
Mixed forage and concentrate diet	Water soluble CHO level of roughage	Reduced	No change	Staerf *et al.* (2012)
>>	Protected fat 0.7 and 1.4%	Increased	Increase fat and protein contents	Ranjan *et al.* (2013)
>>	Piper betle leaves	Increased	Increase fat, protein and lactose content	Santra *et al.* (2013)
Mixed silage concentrate diet	Fibrolytic enzyme of xylanase and cellulose	No change	No change	Dean *et al.* (2013)
Mixed silage, hay and concentrate	Yeast supplements	Increased	Decreased fat	Stella *et al.* (2007)
Total mixed ration	Yeast supplements	No change	No change	Dean *et al.* (2013)
Mixed forage and concentrate diet	Roughage and concentrate	No change	Decrease protein	Kergar *et al.* (2012)
Mixed forage and concentrate diet	Fat supplement	Increased	Increased protein content	Kergar *et al.* (2012)
Mixed grass silage and concentrate	Crude glycerol	No change	Increase protein content	Kass *et al.* (2012)
Mixed legume hay and concentrate	Cumin seed extract supplement in diet	Increased	No change	Miri *et al.* (2013)
Total mixed ration	Vegetable in supplement	Increased	No change	Castro *et al.* (2009)
Total mixed ration	Pellet diet with rumen degradable protein	No change	No change	Laudadio and Tufarelli (2010)

Source: cited by Tripathi (2014)

Effect of Fat Supplements

Fat supplements are used in animal diets not only because it supplies essential fatty acids and fat-soluble vitamins, but also because it provides more energy, approximately twice that of carbohydrates for milk production that enhance productivity of milk. The actual choice of fat or oil and the form by which it is included in the feed is decided by a number of factors.

Supplementation of fat tended to increase milk fat content and yield. Milk fat content does not influence by the source of dietary fat. Supplementation of 2% hydrogenated palm oil or yellow grease in diet of lactating Holstein cows as source of fat improved milk fat content, and the total fat yield increased with yellow grease compared to hydrogenated palm oil feeding (Kargar *et al*., 2012).

Diet and Milk Conjugated Linoleic Acid (CLA) Contents

The discovery of Conjugated Linoleic Acid (CLA) as a strong ant carcinogenic agent attracted research interest on enhancing the CLA concentration in milk through nutritional manipulations. Seasonal variation in milk CLA content also occurred, which is ranging from 0.77 to 1.5 g/100 g total FA in winter with conserved forages and concentrates, and in summer when animals grazed fresh pasture (Lock & Garnsworthy, 2003).

Source of fat and fat supplementation increased and tended to increase total CLA concentrations in milk fat but changing the F: C ratio did not impact CLA levels of the milk. The main CLA isomers are not affected by dietary treatments that have fat supplementation.

Alfalfa hay as a sole source of forage in diets may alleviate effects of dietary treatments on rumen condition and rapid fermentation by inhibiting lactic acid producing bacteria and there by sustaining stable rumen environment. Oelker, Reveneau, and Firkins (2009) observed that any changes in rumen pH with alfalfa hay relative to corn silage based diets decreased the accumulation of biohydrogenation intermediates and thereby total CLA content in rumen of Holstein dairy cows. Yellow grease feeding at 2% in diet of cows increased milk fat CLA without effecting denatures indices (Santra *et al.*, 2013) when compared with similar levels of hydrogenated palm oil.

Milk Protein Content

The nutritional factors that are having major influence on milk protein content are forage-to-concentrate ratio, the amount and source of dietary protein, and the amount and source of dietary fat. Diet can also affect the protein content of milk. Although changes in milk protein are not as dramatic as those observed for milk fat, increases in 0.05 to 0.15 percentage units in milk protein might be observed when the energy and protein content of the diet is manipulated.

Fat supplements in lactating animal diets caused a decline in protein concentration and that attracted the research interest of the basic biology of milk constituent synthesis and regulation in controlling milk composition by dietary manipulation and its influences on the entire animal system from practical feeding to mammary tissue metabolism. The milk nitrogen fractions can be divided as casein, whey, and NPN. Casein comprises about 78% of the nitrogen in milk, whey N is 17% and NPN is approximately 5% (Jenkins & McGuire, 2006).

Influence of Amount and Source of Protein and Fat

The effects of amount and source of protein in the diet have only modest changes in the protein content of milk (Tripathi, 2014). Different protein sources have varying influence on milk protein content, yellow grease feeding at 2% in Holstein cows diet improved milk protein content and yield, while hydrogenated palm oil did not (Kergar *et al.*, 2012).

The milk protein content varies from 2.85 to 3.27% as protein content in the diet ranged from 15.0 to 19.5% that have had a wide variety of protein sources, including rumen-protected amino acids. A major factor is the low transfer efficiency (25 to 30%) of dietary protein to milk is accounting for the inability of diet to alter milk protein content (Tripathi, 2014).

Fat supplements are used to increase energy density of diet and make enough energy available to dairy animal for enhancing milk production (Tripathi, 2014). However, feeding additional fat is often accompanied by a decline in milk protein content. Therefore, fat feeding in dairy animal diets had limited applicability, where milk pricing gave an incentive to protein content (Tripathi, 2014).

Feed Additives

Rumen buffers increase milk fat percentage, and possibly yield, when low-fiber, high-grain rations are fed. Feed sodium bicarbonate with or without magnesium oxide when cows are consuming more than 30 pounds of wet corn silage, fine-ground grain or high levels of rumen-fermentable fiber from byproduct feeds. This will not only help milk fat percentage, but it also will help maintain a healthy rumen environment. Rations in which all the forage is alfalfa generally do not benefit from buffers (Schroeder, 2012).

Niacin can alleviate the milk protein percentage decrease with feeding supplemental fat but also can reduce yield and fat percentage slightly. Niacin most notably helps prevent ketosis in early lactation, especially with over conditioned cows. Feeding niacin to thin cows (body condition score less than 3 at freshening) reduces yield and is not recommended.

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 & 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 (Tyasi, Gxasheka, & Tlabela, 2015). 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. Milk fat depression can be alleviated within seven to 21 days by changing the diet of the cow.

Conclusion and Recommendation

It is concluded that the nutrition affects the quality of milk and even the quantity. Although nutrition is thought to affect quantity of milk yield produced, nutrition also has effects on milk components. Nutritional manipulations of dairy animals enabled in enhancing milk production, alterations in milk fat and protein, and fatty acid. Milk production can be improved up to 50% levels by altering the feed composition with addition of rumen protected supplements. Grain feeding is associated for milk fat depression, while mixed diets promoted milk production and milk protein content.

Milk protein content can be increased by 0.4% unit by altering forage to concentrate ratio. Milk fat is more responsive to dietary alterations than protein and that the fat can be changed over 3% percent unit while protein content less than 1% unit. The biology of milk synthesis relative to circulating nutrient level and timing of delivery to mammary require great research interest.

Based on the above conclusion the following recommendation is forwarded:

- Animal nutrition policy makers should choose suitable nutrition type for effective production.
- There should be a strategy at national level to regulate optimum milk production in dairy cows.
- The government, milk producer and nutrition experts have to work together for proper milk production.

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