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Factors Affecting Milk Composition of Lactating Cows

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Introduction

Many factors influence the composition of milk, the major components of which are water, fat, protein, lactose and minerals.

Nutrition or dietary influences readily alter fat concentration and milk protein concentration. Fat concentration is the most sensitive to dietary changes and can vary over a range of nearly 3.0 percentage units. Dietary manipulation results in milk protein concentration changing approximately 0.60 percentage units. The concentrations of lactose and minerals, the other solids constituents of milk, do not respond predictably to adjustments in diet.

Milk composition and component yields also can be affected by genetics and environment, level of milk production, stage of lactation, disease (mastitis), season and age of cow.

There are various feeding management practices that can enhance levels of milk fat and protein concentration in milk. Feeding strategies that optimize rumen function also maximize milk production and milk component percentages and yield.

Normal Sources of Variation in Composition

Genetics and Environment

Table 1 contains the breed averages for percentage of milk fat, total protein, true protein and total solids. A change in milk composition using traditional breeding techniques occurs slowly, although new techniques of genetic manipulation may allow faster progress in the future. Yields of milk, fat, protein and total solids are not easily impacted by genetics; heritability estimates for yield are relatively low at about 0.25.

Table 1. Breed averages for percentages of milk fat, total protein, true protein and total solids

	Percent			
Breed	**Total Fat**	**Total Protein**	**True Protein**	**Total Solids**
Ayrshire	3.88	3.31	3.12	12.69
Brown Swiss	3.98	3.52	3.33	12.64
Guernsey	4.46	3.47	3.28	13.76
Holstein	3.64	3.16	2.97	12.24
Jersey	4.64	3.73	3.54	14.04
Milking Shorthorn	3.59	3.26	3.07	12.46

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Meanwhile, heritability estimates for milk composition are fairly high at 0.50. Conversely, environmental factors such as nutrition and feeding management will impact yield more than the actual percent composition of the major milk constituents.

The priority placed on each genetic trait depends upon its economic or profit impact. Milk yield per cow tends to receive the most attention by producers. However, component yields should not be overlooked. Genetic selection should be directed toward increasing fat, protein and nonfat solids yields. But, because component percentages tend to have negative genetic associations with yield traits, a change in these percentages is not likely to be achieved through genetic selection alone.

Level of Production

Yields of fat, protein, nonfat solids and total solids are highly and positively correlated with milk yield. Under selection programs that emphasize milk yield, fat and protein yields also increase. However, the percentages of fat and protein in the total composition decrease.

The concept of milk component yield versus milk composition can be illustrated by comparing different bulk tank production averages with similar protein composition. If the tank average increases from 65 to 70 pounds while protein composition remains constant at 3.1 percent, an additional 0.16 pound of protein is produced per cow per day. However, if the percentage of protein increases from 3.1 to 3.2 percent while the bulk tank average production remains at 65 pounds, protein production (yield) increases by only 0.07 pound per cow per day.

Stage of Lactation

The concentration of milk fat and protein is highest in early and late lactation and lowest during peak milk production through mid-lactation. Normally, an increase in milk yield is followed by a decrease in the percentages of milk fat and protein, while the yields of these constituents remain unchanged or increase.

Disease

Although other diseases can affect milk component content and distribution, mastitis has been the predominant disease studied. Table 2 shows the compositional changes in milk constituents associated with elevated somatic cell counts (a measure of severity of the disease). Mastitis results in a reduction in fat and casein content and an increase in whey content of milk. These changes in the milk proteins, in conjunction with alterations in lactose, mineral content and milk pH, result in lower cheese yields and altered manufacturing properties. Milk from cows with elevated somatic cell counts (greater than 500,000 somatic cells/ml) has longer coagulation time and forms weaker curds than milk from cows with lower somatic cell counts.

Season

Milk fat and protein percentages are highest during the fall and winter and lowest during the spring and summer. This variation is related to changes in both the types of feed available and climatic conditions. Lush spring pastures low in fiber depress milk fat. Hot weather and high humidity decrease dry matter intake and increase feed sorting, resulting in lower forage and fiber intake.

Table 2. Change in milk constituents associated with elevated somatic cell counts

Constituent	Normal Milk, %	High SCC Milk, %	Percent of Normal
Milk nonfat solids	8.9	8.8	99
Fat	3.5	3.2	91
Lactose	4.9	4.4	90
Total protein	3.61	3.56	99
Total casein	2.8	2.3	82
Whey protein	0.8	1.3	162
Sodium	0.057	0.105	184
Chloride	0.091	0.147	161
Potassium	0.173	0.157	91
Calcium	0.12	0.04	33

Adapted from Harmon, 1994. *J. Dairy Science* 77:2103.

Age (Parity)

While milk fat content remains relatively constant, milk protein content gradually decreases with advancing age. A survey of Holstein Dairy Herd Improvement Association (DHIA) lactation records indicates that milk protein content typically decreases 0.10 to 0.15 unit over a period of five or more lactations or approximately 0.02 to 0.05 unit per lactation.

Maximizing Rumen Function Can Increase Milk Components

There are several strategies that producers can use to enhance rumen function and the resulting milk components. Producers who use records, such as those provided by DHIA, can critically evaluate their nutrition and feeding management programs.

Feed Intake

Feed provides the nutrients that are the precursors, either directly or indirectly, of the principal milk solids. Thus, an increase in feed intake usually results in the production of a greater volume of milk. In general, the proportional increases in fat, protein and lactose yields are approximately the same as the proportional increase in milk volume. Milk composition changes little.

It is critical to maximize feed intake of cattle so that negative energy balance is minimized during early lactation. As cows consume more energy than they use, body weight is regained, losses in body condition are minimized and cows produce milk of normal fat and protein content. Increasing feed intake, and the resulting overall increase in energy, can increase milk protein content by 0.2 to 0.3 percent.

High-producing cows should eat 3.5 to 4.0 percent of their body weight daily as dry matter. If a herd is consuming less than this, production of solids-corrected milk may be limited. Major factors that can affect feed intake include:

- Feed bunk management (keep feed bunks clean, not empty)
- Feeding frequency
- Feed sequencing
- Ration moisture between 25 and 50 percent (to optimize dry matter intake)
- Social interactions and grouping strategy of the herd
- Abrupt ration changes
- Physical facilities
- Environmental temperature

Increased feeding frequency of low-fiber, high-grain diets increases milk fat levels. The greatest increase occurs in diets of less than 45 percent forage and when grain is fed separately as in parlor feeding. When diets are fed as a total mixed ration, feeding frequency becomes less important as long as the feed remains palatable and is fed and mixed a minimum of once a day. During hot weather, more frequent feeding helps keep feed fresh and palatable.

Forage-to-Concentrate Ratio

On a dry matter (DM) basis, the minimum ratio of forage to concentrate required to maintain normal milk fat percentage is approximately 40 to 60. This ratio should serve only as a guide; other dietary factors influence the general effects that a decreased ratio has upon rumen fermentation. These effects include decreased rumen pH, increased propionic acid production and reduced fiber digestion. Obviously, type and physical form of ingredients that contribute to the forage or concentrate portion of this ratio must be considered.

Grain Feeding

The proper feeding of concentrates involves maintaining proper forage-to-concentrate ratios and nonfiber carbohydrate levels. Feeding appropriate nonfiber carbohydrate levels can improve both milk fat and protein levels, while overfeeding leads to milk fat depression of one unit or more and often increases milk protein percent by 0.2 to 0.3 unit.

Nonfiber carbohydrates (NFC) include starch, sugars and pectin. The percentage of nonfiber carbohydrate is calculated as NFC = 100 – (% Protein + % NDF + % Fat + % Ash). Depending on the digestibility of the neutral detergent fiber (NDF) present, nonfiber carbohydrates should range from 34 to 40 percent of the total ration dry matter. In most instances, a nonfiber carbohydrate level between 36 to 38 percent is considered ideal. This level is typical of diets with less than 60 percent forage. Diets with greater than 60 percent forage may be deficient in nonfiber carbohydrates.

Table 3. Grain feeding guidelines

Breed	Milk Production	Grain Feeding Guideline
Holstein and Brown Swiss	Less than 40 pounds	1 pound per 4 pounds of milk
	40 to 70 pounds	1 pound per 3 pounds of milk
	Greater than 70 pounds	1 pound per 2.5 pounds of milk
Jersey, Ayrshire and Guernsey	Less than 30 pounds	1 pound per 3 pounds of milk
	30 to 60 pounds	1 pound per 2.5 pounds of milk
	Greater than 60 pounds	1 pound per 2 pounds of milk

Adapted from B. Mahanna, 1995. *Hoard's Dairyman*, Vol. 140, No. 15, p. 617.

When feeding for component changes, limit the amount of grain consumed during one feeding to 5 to 7 pounds to avoid rumen acidosis and off-feed problems that result in reduced fat content of milk. Grain feeding guidelines to maximize milk fat and protein production are provided in Table 3. Limit grain consumption to a maximum of 30 to 35 pounds per cow daily.

Manure containing large amounts of undigested corn or with a pH less than 6.0 can indicate too much grain or an imbalance of nonfiber carbohydrates in the diet. Fibrous byproducts such as soybean hulls can replace starchy grain and reduce the severity of milk fat depression in rations high in nonfiber carbohydrate.

Grain Processing

The type of grain and processing method can have a significant impact on the site and extent of starch digestion of a particular diet and resulting milk component composition and yield (Table 4). Generally, ground, rolled, heated, steam-flaked or pelletized grain increases starch digestibility and propionic acid production in the rumen. Steam-flaked corn or sorghum compared to steam-rolled corn or dry-rolled corn or sorghum consistently improves milk production and milk protein yield. In six comparisons, steam-flaked corn increased milk protein percentage and yield and decreased milk fat percentage compared to steam-rolled corn. Milk fat yield remained unchanged in these trials. Twenty-four comparisons of dry-rolled and steam-flaked sorghum have produced similar results. These results are attributed to increased total tract starch digestibility, increased recycling of urea to the intestinal tract and increased microbial protein flow to the small intestine.

Extensive use of grains, such as wheat, that consist of a rapidly fermentable carbohydrate and overprocessing of grains can result in severe milk fat depression, off-feed problems and reduced milk yield. It is important to match carbohydrate and protein sources and to carefully monitor nonfiber carbohydrate levels in the diet to ensure proper fermentation patterns and to maximize milk component content and yield.

Table 4. Rate of rumen starch digestion as impacted by grain type and processing method

Rate	Grain Type/Processing Method
Fast	Dry-rolled wheat
	Dry-rolled barley
	High-moisture corn (ground)
Intermediate	Steam-flaked corn
	High-moisture corn (whole)
	Steam-flaked sorghum
	Dry-rolled corn
	Whole corn
Slow	Dry-rolled sorghum

Ration Fiber Levels

The level of fiber feeding and the physical size of fiber particles contribute to the effectiveness of a fiber source for stimulating rumination (cud chewing), buffer production (salivation) and maintenance of normal milk fat and protein composition. Feeding of finely ground forages inadequately stimulates rumination and lowers saliva production. This results in a rumen fermentation pattern that produces a higher proportion of propionic acid and, in turn, reduces milk fat percentage. In most situations, forage comprises no less than 40 to 50 percent of the total ration dry matter or should be included in the diet at no less than 1.40 percent of body weight. Cows should receive a minimum of 5 pounds of roughage (fiber) that is at least 1.5 inches long per day.

Cows require a minimum acid detergent fiber (ADF) level of 19 to 21 percent in the ration dry matter. Maintain total neutral detergent fiber (NDF) intake above 26 percent of the total ration dry matter. Provide 75 percent of the NDF as forage. Below these levels, cows are at an increased risk for acidosis, feed intake fluctuations, laminitis and rapid and extensive body condition loss especially in early lactation. Suggested guidelines for NDF intakes from forages are presented in Table 5.

Table 5. Forage and total neutral detergent fiber (NDF) intake guidelines

Forage NDF (% of Body Weight)	Total NDF Intake (% of Body Weight)
0.75 - 0.80	1.30 - 1.40
0.85	1.10 - 1.20
0.90 - 1.20	1.10 - 1.20

Adapted from Varga et al., 1998. *J. Dairy Science* 81:3063.

Protein Feeding Guidelines

Generally, dietary crude protein level affects milk yield but not milk protein percent, unless the diet is deficient in crude protein. Normal changes in dietary protein ranges do not consistently affect milk fat percentage. Theoretically, insufficient amounts of rumen-degradable protein might result in decreased milk fat percentage if the concentration of ammonia in the rumen does not support the optimal digestion of fiber and microbial growth.

The crude protein requirement for a 1,350-pound cow producing 3.6 percent milk fat ranges from 14.0 percent of total dry matter (TDM) for 50 pounds of milk to 18.0 percent TDM for 100 pounds of milk. Depending on the stage and level of production, the recommended level of undegradable intake protein (UIP) ranges from 32 to 38 percent of crude protein. Keep soluble protein between 30 to 32 percent of crude protein or about half of the degradable protein intake level.

It is essential to meet the cow's requirement for both crude protein and rumen-undegradable protein to avoid a negative impact on dry matter intake and fiber digestibility. Studies of diets containing no supplemental fat show that each 1 percent increase in dietary protein, within the range of 9 to 17 percent,

Table 6. Summary of feeding management practices and their potential impact on milk fat and protein concentration

Management Factor	Milk Fat (%)	Milk Protein (%)
Increase feed intake	Increase	Increase
Increase feeding frequency	Increase	Increase slightly
Underfeeding energy	Decrease	Decrease
High NFC (> 45%)	Decrease	Increase
Normal NFC (34% to 40%)	Increase	No change
Excessive fiber	Increase slightly	Decrease
Low fiber (< 26% NDF)	Decrease	Increase
Small particle size	Decrease	Increase
High crude protein	No effect	Increase if diet is deficient
Low crude protein	No effect	Decrease if diet is deficient
UIP (34% to 38%)	No effect	Increase if diet is deficient

results in a 0.02 percentage unit increase in milk protein. The additional synthesis of protein by mammary tissue likely is linked to limiting amino acids. Table 6 (page 5) summarizes the various feeding management practices and their potential impact on milk fat and protein concentration.

Summary

Many factors can influence milk composition. This is an important point to remember when evaluating the potential to improve a herd's milk composition and component yields. Certainly, genetics plays an important role, but changes here are slow. Producers who pay attention to detail, keep disease to a minimum and adjust their management program as the seasons dictate will be in the best position to take advantage of nutrition management changes that maximize rumen function. The resulting increase in milk components should help improve their bottom line.

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