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Milk Components: Understanding the Causes and Importance of Milk Fat and Protein Variation in Your Dairy Herd

Jud Heinrichs, Coleen Jones, and Ken Bailey[1]

[1]Department of Agricultural Economics and Rural Sociology

DAIRY& ANIMAL SCIENCE
Department of Dairy and Animal Science
The Pennsylvania State University
324 Henning Building
University Park, PA 16802
(814) 865-5491 • FAX (814) 865-7442
www.das.psu.edu/

Topics include:

Average components by breed
Components in the Mideast federal order
Factors affecting component levels
Nutritional strategies to modify milk fat and protein

INTRODUCTION

Most milk marketing orders in the US now employ a multiple component pricing system that pays producers on the basis of milk fat, true protein, and other dairy solids. This new pricing method derives component values from prices for manufactured dairy products (cheese, butter, nonfat dry milk, and dry whey), which rise and fall with changing market conditions. As a result, milk component levels have taken on new importance in herd management. In addition to being indicators of cow health and nutrition, component levels now directly impact farm income. This factsheet will describe the variation found in production of milk components, factors that contribute to this variation, and strategies to improve component production.

Generally, fat and protein content of milk are positively correlated within a population of dairy cattle; however, different breeds of cattle vary in average component levels (Table 1). Holsteins have the lowest fat and protein content, while Jersey and Guernsey breeds have the highest. Because Holsteins produce more milk, they generally have a higher total yield of fat and protein than other breeds.

Table 1. Average fat and protein content of milk produced by different breeds.

Breed	% Fat	% Protein	F:P[1]
Ayrshire	3.86	3.18	1.21
Brown Swiss	4.04	3.38	1.20
Guernsey	4.51	3.37	1.34
Holstein	3.65	3.06	1.19
Jersey	4.60	3.59	1.28

Source: USDA-AIPL summary of herds on DHI test during 2004.

[1]Ratio of fat to protein.

Production of milk fat and protein can vary tremendously from one herd to another. A recent summary of milk shipped in the Mideast federal order from 2000 through 2002 showed that herd average milk protein ranged from 1.57% to 4.66%, with an average of 3.05%. Milk fat ranged from 1.77% to 5.98%, with an average of 3.76%.

These data represent real herds and actual production. While these data do not provide any information about breed, the range in herd performance is huge. Figure 1 shows information from the same study, but presents the range that includes 68% of the population. Even when the extremes are eliminated, this study indicates that many herds are producing components below average for their market and their breed. This presents an opportunity to improve component production and income from milk sales.

As an example, Table 2 presents some comparisons of the value of milk sold as the component levels change. If a Holstein herd currently produces milk with 3.5% fat and 2.9% protein, that herd is below the breed average for components. In addition, if that herd ships milk in the Mideast federal order, it is also below the market average for component levels. Increasing fat and protein to breed average would increase the value of milk sold by 58 cents per hundredweight. Increasing to market average would gain the herd 72 cents per hundredweight. If the herd could increase component percentages by 0.32 for fat and 0.19 for protein, an extra 90 cents per hundredweight would be generated (these values are the standard deviations reported in Figure 1).

Increases of this magnitude are possible with changes in nutrition and management. What's more, if nutritional changes are implemented it is very likely that milk production will increase along with component levels, which would add even more income. We have developed a simple spreadsheet to help you calculate the gross milk price for various component levels. It is available at www.das.psu.edu/dairynutrition.

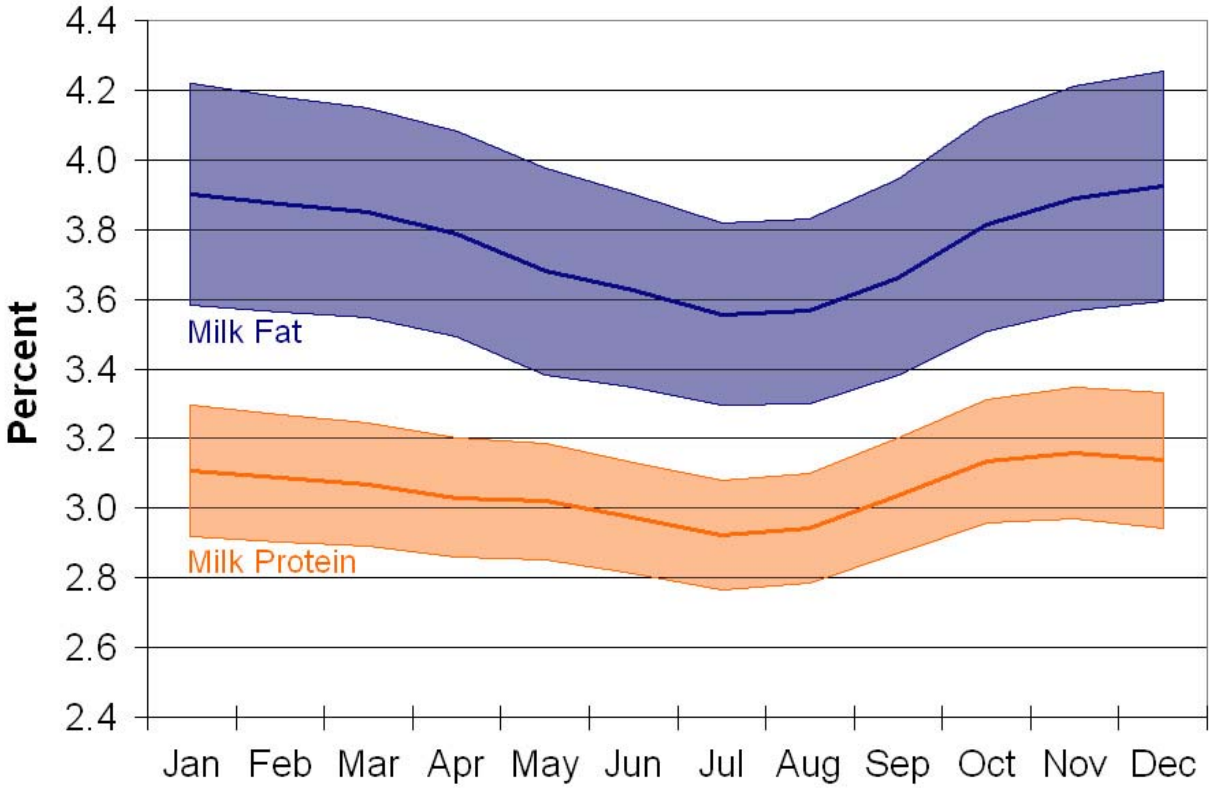

Figure 1. Level of fat and protein varies across herds and seasonally. Ranges represent one standard deviation above and below the average. The solid line in the center of each range indicates the average for that month. For the three years studied, milk fat% averaged 3.76 ± 0.32 (blue), and milk protein% averaged 3.05 ± 0.19 (orange). (Bailey et al., 2005).

Table 2. Comparison of gross milk price at various levels of fat and protein production.[1]

	Fat %	Protein %	Gross Price $/cwt	Difference[2] $/cwt
Current test	3.50	2.90	13.41	0.00
Holstein average	3.65	3.06	13.99	-0.58
Mideast average[3]	3.76	3.05	14.13	-0.72
Increase by 0.5 SD[3]	3.66	2.98	13.83	-0.42
Increase by 1 SD[3]	3.82	3.09	14.31	-0.90

[1]Assumptions: herd SCC of 150,000 and 5.65% other solids for each case. Component prices assumed are averages from Jan. 2000 to June 2005 for the Mideast federal order: fat $1.5256/lb, protein $2.1700/lb, other solids $0.0691/lb, SCC adjustment rate $0.00068. Producer price differential for each case is $1.25/cwt, an average received since 2000 for milk shipped to processing plants located in western Pennsylvania.

[2]Current gross price minus the gross price for each scenario.

[3]Data from summary of milk shipped in the Mideast federal order from 2000 through 2002 (Bailey et al. 2005). One standard deviation (SD) is 0.32% for fat and 0.19% for protein.

FACTORS AFFECTING MILK COMPOSITION

There are many factors that can affect milk fat and protein, and many of them can be manipulated to enable you to achieve higher than average levels of milk components. Keep in mind that herds that are below breed average will have more opportunity to improve component levels. Herds that are already above average may have better success by focusing on increasing milk yield, which will increase the total amount of fat and protein produced.

Factors Other Than Nutrition

Stage of lactation affects milk protein and fat percentages very similarly. The highest amount of protein and fat in milk is found just after freshening, in colostrum. Levels drop to their lowest point between 25 and 50 days after calving and peak at 250 days as milk production begins to decrease.

Age tends to cause both milk fat and protein to decline as the animal becomes older. Milk fat falls about 0.2% each year from the first to fifth lactation likely as a result of higher production and more udder infections. Protein decreases 0.02 to 0.05% each lactation as animals age.

Season dramatically affects milk fat and protein (refer to Figure 1). The hot, humid months (July and August in the NE) depress fat and protein content. There is a gradual increase of protein and fat in milk through the fall and peak levels occur in the colder months of winter. As temperatures increase through the spring, component levels are gradually decreased. These changes may be indicative of feed intake patterns, which are lower in summer due to changes in weather and temperature.

Mastitis infections reduce fat and casein but increase blood protein content of milk. Somatic cell count (SCC) also is elevated during mastitis. Herds that have continuous mastitis and SCC problems take a double or triple hit on milk price. The component value is reduced, plus in some federal orders there is a deduction for SCC over 350,000. Quality premiums from the milk handler may be lost as well.

Milk fat and protein depression also can occur from **mechanical errors,** such as cooling problems in the bulk tank, sampling problems, and over agitation in the pipeline.

Genetics and inheritance account for 55% of the difference between cows in protein and fat content of milk. Table 3 provides heritability estimates for milk and its components. Heritability indicates the proportion of observed differences that are due to genetics, while the reciprocal is assumed to be due to environmental factors. Protein and fat percentages are more highly heritable than yield of milk and components. Milk yield is positively correlated to yield of fat and protein; however, milk yield is negatively correlated to fat and protein percent. For many years, sires have been selected for high yields of milk, which has resulted in very slow increases in fat and protein percentages over time. Herds that are more than one standard deviation below the breed average for fat or protein may benefit from including component yields in sire selection criteria. However, because fat and protein percentages are negatively related to milk yield, changes in herd component percentages are not likely to be achieved through genetic selection alone.

Table 3. Heritability (h^2) estimates for milk and its components.

	Holstein		Jersey	
Trait	h^2	SD[1]	h^2	SD[1]
Fat, %	0.58	0.23	0.55	0.28
Protein, %	0.51	0.14	0.55	0.20
Fat, lb	0.30	52	0.35	50
Protein, lb	0.30	37	0.35	36
Milk, lb	0.30	1444	0.35	1204

[1]Estimate of genetic standard deviation.
Source: USDA-AIPL yield traits definition (May 2005) and trend estimates for cows born in 2000.

Nutritional Factors and Feeding Practices

Of all the factors affecting milk composition, nutrition and feeding practices are most likely to cause problems; however, management changes made here are able to quickly and dramatically alter production of fat and protein. Milk fat depression can be alleviated within seven to 21 days by changing the diet. Milk protein changes may take 3 to 6 weeks or longer if the problem has been going on for a prolonged period. Nutrition or ration formulation changes are more strongly correlated to milk fat content than milk protein. Milk fat can be changed by 0.1 to 1.0 percentage points, while protein is seldom altered more than 0.1 to 0.4 points by nutritional changes. For these reasons, nutrition and feeding management are considered the best solutions to a milk fat or protein problem other than genetics.

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. The other half of milk fat is transported from the pool of fatty acids circulating in the blood. These can originate from body fat mobilization, absorption from the diet, or from fats 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 used by the mammary gland to synthesize milk proteins. Glucose is required to provide energy to support this protein synthesis. Glucose is either formed from the VFA propionate in the liver, or absorbed directly from the small intestine. If too little propionate is absorbed from the rumen, the cow will have to breakdown 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.

Rumen Function. The relative amounts of protein and energy that are available in the rumen at a given time is the major factor affecting rumen fermentation and therefore milk components. Any diet or management factors that affect rumen fermentation can change milk fat and protein levels. Consistently providing adequate energy and protein and balanced amounts of rapidly fermentable carbohydrate and effective fiber are keys to maintaining optimum levels of milk components. The challenge in feeding for milk components is that high energy, low fiber diets that increase milk protein are likely to reduce fat levels. This may also be the case in some diets with rumen modifiers, such as Rumensin®; however, this product has other ways to affect the rumen that do not necessarily alter milk components.

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, feeding rations that encourage sorting, feeding infrequently in a conventional system (non-TMR), failing to push feed up or feed TMR often enough, feeding protein feeds before energy feeds and feeding grain before forage in non-TMR systems. 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 is removed from bunks, and shade or cooling is provided during hot weather to help maintain normal intake and normal meal patterns. Poor ventilation or cow comfort also can depress milk fat and protein production by reducing intake. Finally, make ration changes gradually to allow rumen microorganisms time to adapt. Any reduction in rumen microbial protein production from nutrition or feeding management imbalances will reduce milk protein by way of less microbial protein for the cow to digest and depress fat by limiting VFA production in the rumen.

Body Condition. Proper body condition is essential so that high producing cows can draw on body stores of nutrients to support milk production. If body stores are minimal, yields of milk and milk components will suffer. On the other hand, excessive body condition increases the risk of metabolic problems and calving difficulty. Weight loss in early lactation can increase milk fat content for a short period of time. Both thin and fat cows tend to have low milk fat in later lactation. Protein can be depressed at calving if animals are overly obese or underweight. In addition, some research shows that underfeeding protein during the last three weeks before calving can depress milk protein.

Energy Effects. In general, as energy intake or ration energy density increase and/or fiber decreases, milk fat content will be reduced, while protein is increased. In contrast, as ration fiber levels increase and/or energy is reduced, milk protein is depressed and milk fat is increased. Lack of energy intake or lower ration digestibility may reduce milk protein by 0.1 to 0.4%. This reduction may result from underfeeding concentrates, low forage intake, poor quality forage, 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. However, excessive energy intake, such as overfeeding concentrate, 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. Often this is impossible to achieve with high producing animals.

Protein Effects. A deficiency of crude protein in the ration may depress protein in milk; marginal deficiency could result in a reduction of 0.0 to 0.2%, while more severe restriction of diet crude protein would have greater impact. However, feeding excessive dietary protein does not increase milk protein, as most of the excess is excreted. Dietary protein has little effect on milk fat levels within normal ranges.

Diet protein type also could affect milk protein levels. Use of non-protein nitrogen (NPN) compounds, like urea, as protein substitutes will reduce protein in milk by 0.1 to 0.3% if the NPN is a main provider of crude protein equivalent. Rations higher than recommended in soluble protein may lower milk protein by 0.1 to 0.2 points. NPN 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. Balance rations for crude protein, rumen undegradable protein, rumen degradable protein, and soluble protein. For high producing cows, balancing for amino acids also may be required.

Concentrate Intake. 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; 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 nonfiber carbohydrate (NFC) portion of the diet is highly digestible and can influence both fat and protein in milk. Excessive amounts of NFC can depress fiber digestibility, which reduces the production of acetate and leads to low milk fat (1% or more reduction). At the same time, greater propionate production allows higher milk protein levels of 0.2 to 0.3%. Generally an NFC of 32 to 38% of ration dry matter is recommended to optimize production of milk fat and protein.

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. Low forage intake can cause a major reduction in the fat content of milk due to low fiber levels. 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.

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. Monitor ration particle size to ensure that adequate effective fiber is provided, TMRs are mixed properly, rations are distributed evenly to all cows, and sorting is minimal.

Added Fat or Oil. Adding fat to the ration can affect milk component levels depending on the amount and source of fat. Fat is generally toxic to rumen microbes and may reduce fiber digestibility when fat from natural sources exceeds 5% of ration dry matter. If rumen inert or bypass 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. 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. This may occur due to reduced blood glucose levels.

EXTREMELY HIGH MILK FAT

High milk fat content often occurs in herds that are off in 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. 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.

MAINTAINING COMPONENT LEVELS

Recommendations for normal fat and protein content can be achieved by feeding a balanced ration that meets the chemical and physical needs of the cow. Key management practices to accomplish this goal include: regular forage tests for energy, minerals and protein; regular tests of TMR and concentrates to see if they meet herd requirements; evaluation of forage and TMR particle size; use of production records to track component yields; and use of body condition scoring to evaluate the success of nutritional programs.

Monitor milk component percentages from your milk handler or DHI records by month. Over time this will allow you to develop a normal range. If components suddenly drop out of their normal range, investigate and find the cause. Paying close attention to component levels may also allow you to make nutritional changes in response to market conditions. Any decisions of this kind should be analyzed to determine the additional cost compared to the additional revenue.

Reference

Bailey, K. E., C. M. Jones, and A. J. Heinrichs. 2005. Economic returns to Holstein and Jersey herds under multiple component pricing. J. Dairy Sci. 88:2269-2280.

For additional information, see the Dairy and Animal Science fact sheet “Trouble-shooting Problems with Milkfat Depression” (DAS 99-2) by V. A. Ishler and R. S. Adams. Available at http://www.das.psu.edu/dairynutrition/documents/lowmilkfat.pdf.

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