FACTORS AFFECTING PROTEIN AND SOLIDS-NOT-FAT (SNF) CONTENT OF MILK

by

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Since the development of the Babcock fat test 100 years ago, milk has been bought and sold largely on the basis of its fat content. With the continued decrease in market value of milk fat and the large surplus of butter, milk marketing organizations are attempting to change payment of milk to true market values for milk fluid and its constituent nutrients. Consequently, it is important to understand the biological variation that exists in milk composition, what causes this variation, and how we might change composition in the desired direction. An approximate average composition of farm-produced milk in the U.S. is shown in Table 1 (right-hand column). Data are from analyses of Dr. D. M. Barbano who surveyed monthly the composition of milks received at 50 cheese plants located in 19 different states during 1984.

Fat percentage of milk is the most variable and most widely measured constituent since payment traditionally has been based on fat content. Measurement of fat has served the marketing, breeding, and feeding phases of the dairy industry well since variation in fat content is associated consistently enough with variation in other constituents to allow prediction of the change in these constituents that would accompany a change in fat content. For example, seasonal variation in milk composition is conspicuous. Data in Table 1 show low fat percentages in summer and high values in winter. Milk protein percentages vary in the same direction but the relative change is much smaller. The crude protein percentage was calculated by measuring total nitrogen content of milk and multiplying it by 6.38. Milk protein contains 15.67% N in contrast to the 16.0% assumed for most proteins for which crude protein is calculated by multiplying N x 6.25. True protein content of milk is usually 95 percent of crude protein and casein is about 82 percent of true protein (Table 1).

Table 1. Seasonal variation in milk composition.

	Month of the year or yearly average						
Milk constituent	Jan	Mar	May	July	Sept	Nov	Ave.
Fat	3.87	3.65	3.50	3.40	3.60	3.78	3.61
Crude protein	3.34	3.27	3.20	3.13	3.29	3.38	3.27
True protein	3.19	3.12	3.04	2.97	3.12	3.23	3.11
Casein	2.62	2.56	2.49	2.43	2.56	2.65	2.56
Solids-not-fat	8.77	8.72	8.72	8.56	8.60	8.77	8.68
Lactose	4.55	4.52	4.55	4.49	4.47	4.59	4.54
Ash	.71	.70	.71	.72	.73	.75	.72
Total solids	12.47	12.14	11.96	11.74	12.09	12.50	12.14
Water	87.53	87.86	88.04	88.26	87.91	87.50	87.86

Source: Barbano, 1990.

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The above data also show that variations in lactose and ash are quite small. Thus, variation in SNF (crude protein + lactose + minerals) primarily is due to variation in milk protein content.

Although regional differences existed in source data used for Table 1, the noted seasonal variation was very similar regardless of region. Main regional differences involved milk fat percent which was lowest in the South (3.39%) and milk protein percent which was lower in the Northeast and South (3.26 and 3.22%).

Changing Milk Composition Through Genetics

Changing milk composition through animal selection is possible. Despite the appearance that milk pricing formulas pay on percent composition, yields of milk fluid and of solid nutrients determine pay. For example, a base price of $13.50 for 3.5% milk with a fat differential of $.10 for each change of .1% in fat indicates that 100 pounds of milk fluid without any fat is worth $13.50 minus (35 x $.10) or $10.00. The 3.5 pounds of fat is worth $3.50 to the dairyman. A differential for milk protein could be included also. Thus, a dairyman should select for the yield of those constituents that are of most economic value to him. The genetic correlations between milk yield and yields of fat and protein are very high (> than .80) as is the genetic correlation between yield of protein and yield of fat. Thus, animal factors which control yield traits are so closely related that yield of milk fluid, fat, or protein can not be increased without causing a simultaneous increase in the yields of the other two. If selection emphasis were placed on milk composition instead of yield, it would be possible to change composition but milk yield might be depressed considerably because negative genetic correlations exist between yields and percentages of each milk solid constituent (Wilcox, et al., 1971).

In summary, yield and percentage traits for milk and milk components are so highly correlated that even a penalty for fat production will not be an economic incentive for dairymen to select for higher milk protein or SNF percentages in preference to higher yields of milk protein and SNF.

Changing Milk Composition Through Nutrition

Nutritional factors that affect percentages of milk protein and SNF are the main emphases of this paper. Nutritional effects on milk fat percent also are mentioned when interrelated. Factors to be discussed include 1) energy intake, 2) added fat, and 3) dietary protein percent. Related topics considered within these three areas include forage particle size, amount and solubility of dietary starch, and effect of some feed additives. These nutritional effects are exerted through changes in availability of the blood-borne nutrients that are presented to secretory cells in the mammary gland.

The essential amino acids and most non-essential amino acids needed for milk protein synthesis are derived from blood as is glucose. Glucose is required for production of lactose and for energy to drive the metabolic activity that occurs within the mammary gland. Glucose may also be a source of some carbon skeletons needed to synthesize certain amino acids and the glycerol needed for milk fat synthesis. Acetic acid absorbed from the rumen is the primary precursor of short-chain milk fatty acids (4 to 14 carbons) produced in the mammary gland.

The longer chain fatty acids except palmitic acid generally are transferred from the blood to milk and are not synthesized in the mammary gland. Propionic acid absorbed from the rumen is a primary precursor of blood glucose produced in the liver.

Energy Intake. Energy intake has been shown to be the primary nutritional factor that affects milk protein and SNF percentages. Factors affecting energy intake which will be discussed include dry matter intake, substitution of concentrates for forages (forage:concentrate ratio), and digestibility of starch. Increasing energy intake with added dietary fat will be considered separately.

Many experiments have demonstrated that underfeeding results in a drop in protein and SNF contents of milk and that feeding at levels above accepted standards tends to increase these contents. Greater depressions in protein and SNF occur due to substandard feeding than the increases that can be effected through high-energy feeding. Thus, amount eaten regardless of diet composition can have some effect on milk protein content. An overall summary of the effect of dry matter intake on milk protein percent is shown in Figure 1.

Energy intake usually is increased by increasing the proportion of concentrate in the diet. This approach changes the forage:concentrate ratio. In most experiments which compared varying proportions of forage and concentrate, the forages were alfalfa hay or haylage, corn silage, or their combination. Concentrates generally were based on ground corn. The trend is for milk fat percent to decline and milk protein percent to increase as percent concentrate in the diet increases.

Figure 2 summarizes the typical changes in milk protein and milk fat percentages that are associated with change in diet energy concentration. Variation in diet energy content primarily was due to change in concentrate percent from 30 (low-energy diets) to 75 (high-energy diets) while forage components consisted of corn silage, alfalfa, cottonseed hulls, perennial peanut, or sugarcane bagasse. The data set included 1688 individual cow responses to dietary treatments in 20 separate experiments at the University of Florida from 1970-85. The experiments had been designed to compare factors such as forage:concentrate ratio, diet protein percent, protein source, addition of whole cottonseed, and inclusion of buffers. Data in Figure 2 show a linear decline in milk fat percent as dietary energy intake increased. However, in some experiments, milk fat percents were maintained at intermediate energy levels.

Diet changes which tend to produce a high proportion of propionic acid relative to acetic acid in the rumen usually reduce milk fat percent. The drop in fat percent usually is compensated for by a small increase in milk protein percent and a slight increase in milk yield. Feeding high proportions of concentrate relative to forage usually results in a lower milk fat percentage along with less acetic acid and more propionic acid production. In some experiments the efficiency of recovery of dietary energy in milk energy is reduced. However, with proper processing of starchy grains, it may be possible to maintain or improve efficiency of energy conversion by effecting an increase in production of milk which is slightly higher in milk protein and lower in milk fat. For example, three recent experiments at the University of Arizona which utilized steam-flaked sorghum grain stimulated increased milk yield and higher

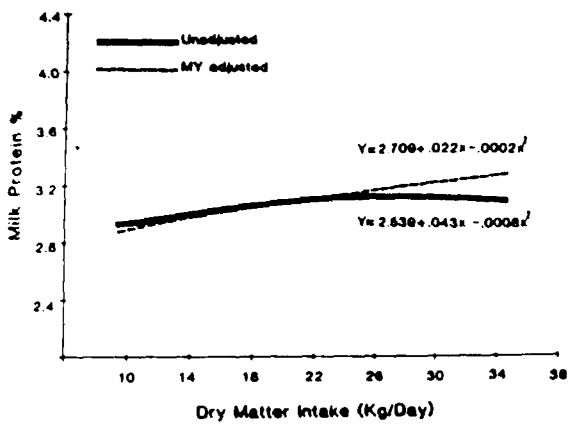

Figure 1. Milk protein percentage response to dry matter intake unadjusted or adjusted for level of milk yield (MY).

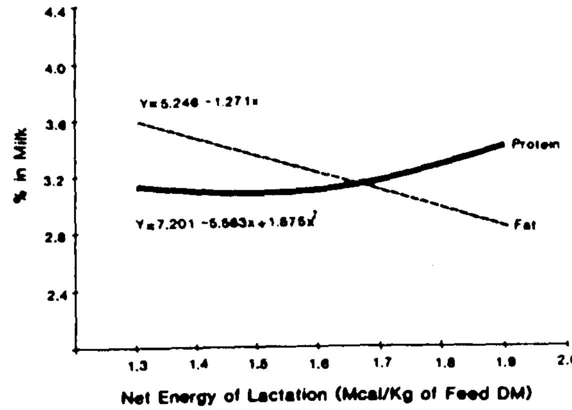

Figure 2. Milk fat and milk protein percentage responses to concentration of estimated net energy of lactation in complete diets (DM = dry matter).

milk protein percentages with only moderate milk fat depression (Table 2). Although, molar proportions of rumen volatile fatty acids were not reported, it is probable that some change in rumen acetic:propionic acid proportions occurred. The Arizona researchers feel that the major gain in efficiency is through improved starch utilization. Their data suggest that moderate flaking to a bulk density of 34 pounds per bushel is adequate compared to thinner flaking (e.g. bushel weights of 25 or 21 pounds) which they showed resulted in more rapid starch degradation.

Table 2. Effect of steam flaking of sorghum grain on milk production efficiency and milk composition.

	Experiment 1		Experiment 2			Experiment 3		
Response	DRS	SFS	DRS	SFS	Mix	DRS	SFS1	SFS2
DM intake, kg/day	20.7	20.3	26.1	24.8	29.4	25.8	25.4	23.8
Milk yield, kg/day	28.1	31.5	29.4	31.0	30.9	30.0	33.3	31.7
FCM yield, kg/day	28.2	29.8	30.6	30.8	29.7	30.4	31.6	29.4
Milk fat %	3.57	3.20	3.73	3.64	3.33	3.40	3.23	3.05
Milk protein %	2.90	2.98	2.95	3.10	3.06	3.14	3.20	3.17
Efficiency, FCM/DMI	1.38	1.49	1.17	1.24	1.01	1.18	1.24	1.26
Apparent digestibility								
Starch, %	80	97	69.8	92.3	82.5			
NDF, %	39	37	47.2	35.3	41.0			
Steam flaking, lb/bu		25		25			34	21

DRS = dry rolled sorghum grain, SFS = steam-flaked sorghum grain, FCM = fat corrected milk.

Added Dietary Fat. In contrast to increasing energy through increased dry matter intake, increased percent concentrate, or improved starch utilization, added dietary fat usually decreases milk protein percent. A large number of the experiments that reported depression of milk protein percent with added fat utilized whole cottonseed as the fat source. Although there are a few exceptions, recent experiments confirm that added fat regardless of source reduces milk protein percent. Amount of depression is usually .1 to .3 units. The decline in protein is greatest in the casein fraction. However, the proportional decline in casein may not be greater than the decline in other protein and nonprotein nitrogen fractions. Current data suggest that the protein depressing effect of dietary fat involves post ruminal metabolism since feeding either rumen unprotected or protected fat depresses milk nitrogen. Importantly, inclusion of rumen protected methionine and lysine in diets that contained added fat attenuated partially the depression in total milk nitrogen and casein caused by the added fats (DePeters and Palmquist, 1989). This and a number of other recent studies suggest that dietary protein interacts with fat. Furthermore, increased absorption of protein and of specific limiting amino acids likely will remove much of the depression in milk protein percentage that is due to added dietary fat.

Dietary Protein. For many years it has been accepted that moderate increases in protein content of the diet have no effect on milk protein percent other than a small increase in the nonprotein nitrogen content. However, Emery concluded from his research review that for each 1% increase in dietary protein between 9 and 17% there was an increase of about .02% in milk protein content. In the data set represented in Figure 1, the increase was .015% for each 1% increase in dietary protein between 12 and 16% of total diet dry matter. Recent studies with abomasal protein administration usually resulted in an increase in milk protein content. Provision of limiting amino acids is the probable mode of action since abomasal infusion of a combination of methionine and lysine results in a modest increase in milk protein content. Feeding protected methionine or corn gluten meal, an excellent source of methionine, also increased milk protein percent in some studies but not in others.

Feeding of protein supplements which are relatively undegradable in the rumen can lower milk protein percent. Dorminey and Harris have just completed a study comparing hydrolyzed feather meal with soybean meal in complete diets for lactating cows which provided either 14 or 18% crude protein. Feather meal at 3 percent of diet dry matter gave a significant response in milk yield over soybean meal in 14% crude protein diets but not at 18%. These results suggest that feeding a high quality, less degradable protein can spare total dietary protein. There was, however, a significant depression in milk protein percent in cows supplemented with feather meal. Minnesota workers at the 1990 ADSA meetings reported a similar effect with a mixture of animal byproducts which included feather meal. North Carolina workers found some depression in milk protein percent when cows were treated intraperitoneally with branched-chain amino acids. Although not reported as statistically significant, studies at Illinois showed that abomasal infusion of arginine resulted in milk protein percent values which were below control values by more than two standard deviations. These results suggest that composition as well as concentration of dietary protein affect mammary gland metabolism and resultant content and yield of milk protein.

Bovine somatotropin (BST) through its effect upon adipose tissue metabolism has an amino acid conservation effect. Less oxidation of amino acids is required to support cell metabolism because other oxidation substrates are made available, namely, glucose, acetate, and fatty acids. Despite this increased availability of amino acids for total protein synthesis, milk protein percentage usually decreases with BST treatment, particularly during early lactation with its associated negative energy and nitrogen balance. This decrease in milk protein percentage probably occurs because in proportion to the precursors for lactose and milk fat synthesis, the amino acids needed for milk protein synthesis are limiting. Consequently, the increased amount of milk fluid produced as a result of increased lactose synthesis will contain a normal or elevated fat content but a relatively depressed protein content.

Summary

Milk protein and SNF percentages vary together and can be changed through dietary manipulation. However, the amount of change possible is small compared to the change that could be effected in milk fat percentage. Dietary energy level as influenced by extent of carbohydrate utilization is the major factor affecting milk protein percentage. Unfortunately, supplemental energy provided through dietary fat usually depresses milk protein by .1 to .3 percentage units. Increasing dietary crude protein usually has little or no effect on milk protein percentage. However, dietary protocols which increase intestinal absorption of limiting amino acids might increase milk protein by .1 to .2 percentage units particularly when they are included with diets where added fat has depressed milk protein percentage.

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