UNIVERSITY OF MINNESOTA

Dairy Extension
Department of Animal Science
101 Haecker Hall
1364 Eckles Ave.
St. Paul, Minnesota 55108

(612) 373-1014

Dairy Update

FACTORS AFFECTING THE PROTEIN AND SOLIDS-NOT-FAT CONTENT OF MILK

J. G. Linn, Extension Dairy Specialist, and
D. E. Otterby, Professor of Animal Science

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The pricing of milk on a component basis and the introduction of protein testing in DHI has raised several questions as to how milk protein and solids-not-fat content can be raised. This paper outlines the synthesis of milk protein and lactose and the factors affecting their content in milk.

MILK COMPOSITION

The components of milk can be divided into 2 main categories, water and total solids. The total solids fraction includes fat and solids-not-fat (SNF) which is comprised of lactose, protein, minerals and vitamins. The average analysis of milk composition is listed in table 1.

Table 1. Average Composition of Milk.

Component	Percent of total
Water	87.2
Total solids	12.8
Fat	(3.8)
Solids-not-fat	(9.0)
Lactose	(4.8)
Protein	(3.5)
Minerals	(.7)
Vitamins	(?)

The composition of milk can vary considerably depending on several factors (breed, nutrition program, mastitis, stage of lactation and others). A recent study by the Food Science and Nutrition people at Minnesota show the extent of this variation (table 2). Bulk tank milk samples were taken from 99 dairy herds in Minnesota, Western Wisconsin and Eastern South Dakota. Most herds sampled were Holstein but Jersey (6), Guernsey (8), Brown Swiss (5) and mixed breed (9) herds also were included. The variation from the average value given for each milk component listed in table 2 should be kept in mind when evaluating individual herd milk components.

Table 2. Mean and Variability of Various Milk Components.

Component	Mean (%)	Standard deviation	Range (%)
Fat	4.00	.529	2.69 - 5.87
Protein	3.43	.240	2.92 - 4.34
Lactose	4.92	.172	4.42 - 5.31
SNF	9.06	.278	8.43 - 9.76

MILK PROTEIN

Approximately 95% of the total protein (nitrogen x 6.38) in milk is true protein (casein, lactalbumin and lactoglobulin) and 5% is nonprotein nitrogen (NPN). Casein protein, the major component used in cheese making, represents between 78 and 82% of the true proteins found in milk. Most of the NPN found in milk is in the whey fraction and is much more variable than casein. Minnesota DHIA and most other milk plants testing for protein are determining the total protein content of milk.

Milk protein synthesis - Over 90% of the proteins found in milk are synthesized in the mammary gland from substrates absorbed from blood. The main substrates available are: acetic acid, glucose, essential and nonessential amino acids. Blood is the only source of the essential amino acids, whereas both glucose and acetic acid can serve as energy sources and substrates for the synthesis of non-essential amino acids within the mammary gland. The following diagram briefly outlines protein and lactose synthesis in the mammary gland.

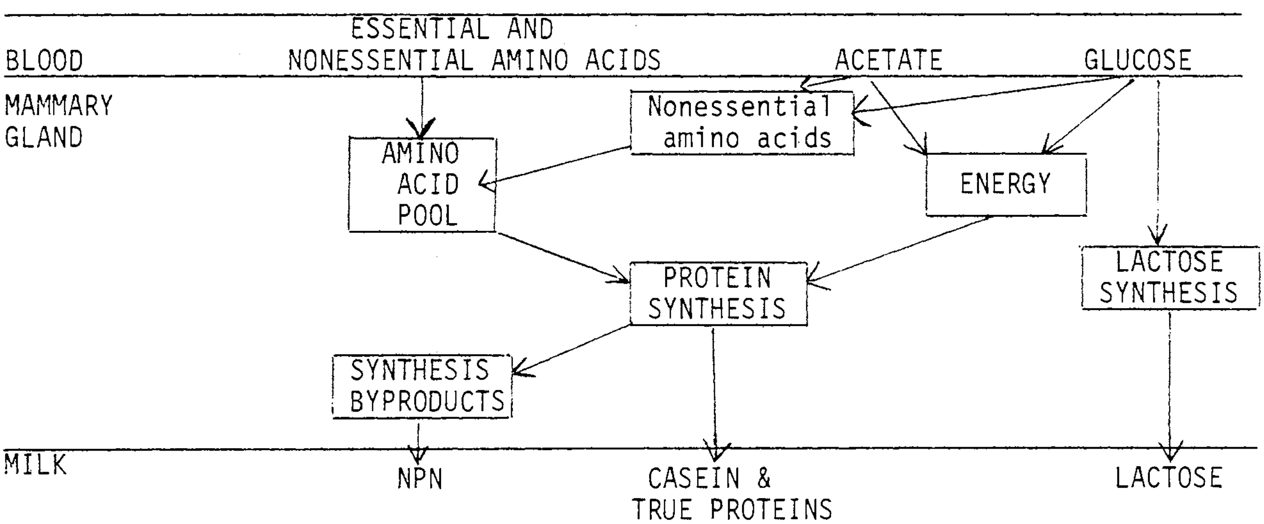

Figure 1. Protein and lactose synthesis in the mammary gland.

FACTORS AFFECTING MILK PROTEIN CONTENT

<u>Nutrition</u> - Restricting dietary energy intake of lactating cows to 70% or less of their requirement will reduce milk solids and consequently milk protein percentage and yield. Milk solids will be reduced .3 to .5% units and milk protein percentage by 5 to 6% with severe underfeeding.

On the other hand, increasing the grain or energy content in the diet can have a positive affect on milk protein percentage. High energy diets increase the production of propionic acid in the rumen which increases glucose supplies to the mammary gland resulting in increased protein synthesis. Most of the increased protein content of milk with high grain diets is in the casein fraction and not NPN. However, dietary levels high enough to elicit a significant milk protein response usually depress milk fat percentage substantially. Increasing fiber content of diets above that necessary to maintain normal milk fat percentages has little or no effect on milk protein percentage.

The addition of animal or vegetable fats (oils) to lactating cow diets will generally depress milk protein by .1 to .3% units. The form of energy needed to increase milk protein content with high energy rations appears to be carbohydrates rather than fats or oils.

The protein content of the diet will affect milk yields more than milk protein content. In diets containing 9 to 17% crude protein, increases of .02% units in milk protein were observed for each 1% unit increase in dietary protein. Thus, about the maximum milk protein percentage response expected to increased dietary protein would be about .16% units. Also, the increases in milk protein content associated with increased dietary protein are in the NPN fraction rather than casein or true protein. Severe restrictions in dietary protein will limit blood supplies of essential amino acids available to the mammary gland for protein synthesis and thus, reduce milk protein content.

It is highly unlikely any one or two specific feeds will have a significant effect on milk protein content. Rather the balance of nutrients (protein, energy, minerals and vitamins) and feeds (forages and grains) in diets will influence milk protein content along with milk yield. The bottom line is, feeding will have very little or no effect on milk protein content when rations are balanced for optimal milk production.

Breeds and genetics - Breeds with high milk fat percentages also have the highest protein percentage, but the differences between breeds are greater for fat than protein (table 3). Milking Shorthorn have the highest protin to fat ratio whereas Guernseys have the lowest. However, the total cheese yield or solids produced will be what cheese and milk plants will be concerned with and payments will reflect yields more than percentages of protein, fat or solids. For example, a Jersey producing 40 lb of 3.88% protein milk yields the same amount of protein for cheese as a Holstein producing 48 lb of 3.20% protein milk.

Table 3. Breed Averages for Fat, Protein and Fat to Protein Ratios.

Breed	Fat (%)	Protein (%)	Protein:Fat
Ayrshire	3.97	3.35	.84
Brown Swiss	4.11	3.60	.88
Guernsey	4.75	3.60	.76
Holstein	3.62	3.19	.88
Jersey	4.95	3.88	.78
Shorthorn	3.67	3.31	.90

Genetic selection for high milk yields and high concentrations of fat and protein is probably the only way a dairy producer can permenantly alter milk protein yields. Dairy producers who have selected sires solely on milk production (PD milk) have tended to decrease fat and protein percentages in milk whereas those selecting for both milk and fat (PD $) also have increased milk protein concentration.

Age - The percentage of total protein in milk drops only slightly with age and not as much as fat or SNF. However, casein and other true proteins decrease greater than total proteins with maturity. Thus, milk from older cows contains more whey proteins and NPN than milk from younger cows. Maintaining a young herd for higher percentages of true protein may not be beneficial as milk yield from young cows is generally lower.

Stage of lactation - The changes in milk composition during lactation are shown in figure 1. The highest protein content in milk occurs just after calving and is associated with the immunoglobulin content of colostrum. The lowest protein content occurs at peak lactation and then slowly rises through the end of lactation.

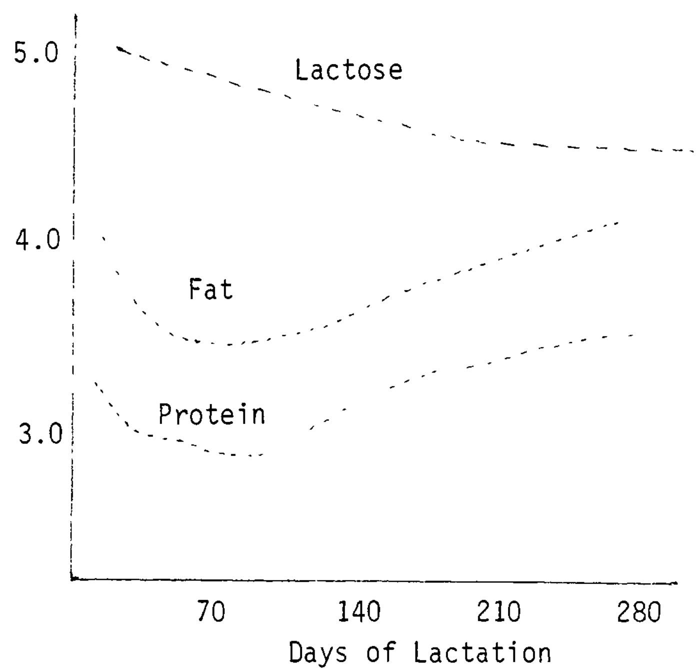

Figure 1. Change in milk composition with stage of lactation.

Seasonal influences - The highest milk protein contents normally are associated with fall and spring. In fall and early winter, the feeding of stored feeds and higher grain diets tend to increase milk protein content. Lush spring pastures also tend to increase milk protein content. However, these observations were made following older or foreign country management conditions which differ considerably from today's practices.

Temperatures above 85^{o}F with high humidity for extended periods of time will decrease both milk yield and composition. Cold temperatures (below 0^{o}F) may tend to raise milk protein and SNF content. However, temperatures between 25 and 70^{o}F should have no affect on milk composition.

Milking frequency - With twice a day milking at nearly equal intervals, milk protein content and other components should be similar for morning and evening milkings. Failure to remove milk by incomplete milking or skipping a milking will decrease milk composition as well as milk yields. Three times a day milking with equal intervals should not affect milk protein content.

Mastitis - Total milk protein does not change appreciably with increasing somatic cells. However, synthesis of proteins in the mammary gland decreases while those transfered from blood increase. From a cheese processing standpoint, this is undesirable because casein content is decreased while NPN and less valuable whey proteins increase.

FACTORS AFFECTING SOLIDS-NOT-FAT CONTENT OF MILK

The solids-not-fat (SNF) component of milk is composed of protein, lactose and minerals. The mineral content remains relatively constant at .7% and therefore, variations in SNF content reflect changes in protein and lactose. The factors affecting milk protein content are described above. Changes in milk SNF other than those associated with protein will be discussed here.

FACTORS AFFECTING SNF

Changes in the SNF component of milk will mainly reflect changes in the milk protein content. This will be particularly true with increases in SNF. Changes in lactose content are less likely to occur because of its role in determining the osmotic pressure in milk.

Breed - The breed effect on protein, lactose and SNF are shown in table 1. These values are averages and it must be kept in mind that the variation of these milk components is greater within breeds than across breeds.

Table 1. Breed Averages for Protein, Lactose and SNF.

Breed	Protein (%)	Lactose (%)	SNF (%)
Ayrshire	3.35	4.46	8.51
Brown Swiss	3.60	4.67	8.97
Guernsey	3.60	4.76	9.06
Holstein	3.19	4.57	8.46
Jersey	3.88	4.81	9.39
Milking Shorthorn	3.31	4.61	8.62

Environmental - Approximately 60% of the variation in milk components is genetics and only 40% is environmental. Since milk components can not be elevated above genetic limits, environmental factors will be primarily responsible in achieving genetic maximums. Table 2 summarizes some of the environmental and management factors affecting the protein and lactose content of milk.

Increasing the energy content of diets fed to lactating dairy cows tend to increase the SNF content of milk through increased protein. Changes in milk lactose content are relatively small and require significant increases in blood glucose levels to elicit increases. Restrictions in dietary energy to 30% or below requirements decrease both milk protein and lactose content.

Cold temperatures ($<0^{o}F$) tend to increase whereas high environmental temperatures ($>85^{o}F$) lower SNF content. Seasonal changes are likely related to changes in temperatures, feeds, calving schedules and other factors.

Diseases which elevate body temperatures usually decrease SNF content as well as milk yield. Mastitis or increases in somatic cells decrease milk SNF content. Lactose accounts for nearly all the drop as total protein content changes very little with mastitis infections. Sodium and chloride are increased in mastitic milk to compensate for the decline in lactose and maintain osmotic pressure.

Table 2. Factors Affecting Milk Protein and Lactose Content[a].

Factor	Protein	Lactose
Mastitis	Whey protein and NPN increase; true protein decreases; total protein constant	Decreased
High dietary energy (Excess feeding)	Slight increase	No change
Underfeeding	Decreases	Slight decrease
Stage of Lactation		
Colostrum	Increased	Constant or slightly lower
Early	Lowest level	Highest level
Middle	Gradual increase	Constant or slight decline
Late	Gradual increase or constant	Slight decline

[a]Changes are in relationship to average lactational values within a breed.

SUMMARY

Breeding for high protein content and milk yield appear to be the only significant management practice producers can use to improve milk protein and SNF content and yields. Routine daily management practices will have very little effect on milk protein or SNF content. Nutrition programs designed for maximum milk production also will support high milk protein and SNF percentages. Elevating dietary protein amounts above requirements to increase milk protein content will not be economical. Maximal milk lactose contents will only be achieved in cows relatively free of mastitis. Further research evaluating specifically the effects of feeding and management strategies on milk protein and SNF content are needed.

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