Milk Protein

As component pricing based on solids not fat and/or protein becomes more a standard in the industry, production of milk components, particularly protein, will receive more emphasis. In addtion, methods of measuring and reporting milk protein will also become more important. The average composition of milk from Holstein cows is presented in Table 1 (4,7).

Table 1. Composition of milk

Item	Average milk composition %
Water	87.00
Lactose	4.90
Fat	3.70
True Protein	3.00
Crude Protein	3.10
Casein	2.60
Ash	.80
Other	.50

Historically, milk protein has been estimated by Kjeldahl determination, which measures the total nitrogen content in milk. Nitrogen is released from protein and other nitrogen compounds in milk and converted to ammonia through acid digestion in the Kjeldahl procedure. Crude protein (CP) is estimated by multiplying the N value by 6.38, the average N content in milk protein (2). Protein determined in this fashion is referred to as crude protein because N comes from true protein and nonprotein sources. As milk pricing places more emphasis on protein, there will be more emphasis on measuring true protein (TP) not crude protein, as true protein has nutritional value. In addition, milk protein yield will become increasingly important.

Typically, TP is 95 to 97% of CP. In Table 1, CP is 3.10% whereas TP is 3.00%. The difference represents the nonprotein N (NPN) constituents in milk, which are ammonia, urea, creatine, creatinine, uric acid, orotic acid, peptides, hippuric acid, amino acids, and other compounds (2). Casein, the milk protein important in cheese manufacturing, is typically 75 to 85% of the CP and 85 to 90% of the TP in milk. Whey proteins constitute the difference in casein content and true protein content in milk.

These values are not constant, but can be influenced by diet, season, breed, mastitis, and stage of lactation, among other factors (2,4). The variation in milk protein and other components is great enough that they can be selected for in genetic programs. Genetic correlations and phenotypic correlations are almost identical (4). The influence of nutrition on milk protein has been variable, but increasing energy intake and dietary crude protein have been associated with small increases in milk protein content (3). Improving the supply of methionine and lysine have resulted in increases in milk protein content (1). Dietary fat has consistently been associated with reductions in milk protein content and increases in milk protein yield. Milk protein content is negatively correlated with milk yield (4). Thus, as milk yield increases we would expect protein content to decrease. The decrease is small, but we would expect protein in milk at 70 lbs to be 2.92% and at 80 lbs to be 2.89%.

The benefit of changing milk composition by management or genetic selection depends on the value of the product and how the milk will be used. Casein is the primary protein product of value in milk for cheese manufacturing. As milk fat and casein decrease, cheese yield will decrease. The Van Slyke and Price formula for Cheddar cheese yield predicts yield based on the chemical analysis of milk:

Percent Yield = {[0.93*F + (C-.1)]*1.09}/(1-W)

- F = % fat in milk
- C = % casein in milk
- W = % moisture in the cheese/100

Protein content of milk may be measured by three methods:

1. Kjeldahl
2. Udy dye binding
3. Infrared reflectance.

Kjeldahl measures total nitrogen in milk (CP=6.38*N); Udy dye binds only to protein (Casein and whey protein); infrared measures true protein in milk. Data from Frank et al (7). compared Kjeldahl and Udy dye measures of milk protein from samples in California.

Method	**Mean**	**Range**
Kjeldahl	3.32%	2.66 - 4.41%
Udy	3.15%	2.56 - 3.93%
Casein Content as percent of total crude protein		
Kjeldahl	76.4%	69.1 - 80.4%
Udy	77.0%	72.8 - 80.7%

Infrared analysis measures true protein in milk. Nonprotein nitrogen is composed of milk urea, amino acids, uric acid, creatine and creatinine. Most DHIA laboratories use infrared analyzers to measure true protein in milk. However, since infrared will not directly measure NPN in milk, infrared analyzers must be calibrated with Kjeldahl analysis to report total CP. NPN in milk is measured by precipitating true protein in milk and measuring the N content of the supernatant. Infrared analyzer is then adjusted to total protein based on the NPN to CP content of the calibration samples. The adjusted value is reported on the DHIA record. This creates a problem because the NPN to CP ratio is not constant and will vary as a function of the urea content in milk. For example, calibration samples may contain the following nitrogen fractions (5):

True Protein	NPN	Total CP	IR Adjustment
1.94	.06	2.0	2.003
2.38	.12	2.5	2.501
2.88	.12	3.0	2.999
3.40	.10	3.5	3.498
3.76	.24	4.0	3.997

Regression of TP on total CP to calibrate the infrared machine yields the following:

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Total Protein = -.0723 + 1.0697*True Protein reading
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Now suppose the following milk is analyzed:

True Protein	NPN	Total CP	Reported CP IR Adjustment
3.00	.26	3.26	3.137
2.50	.05	2.55	2.602

The sample which has 3.26% CP is reported as 3.137. Since the NPN level in this milk is higher than in the calibration set, the adjustment is not sufficient to represent the total N content in the milk. The sample with low NPN is reported as higher in CP, 2.602 than is actually in the milk because the NPN content is lower than in the calibration set. To further compound the problem, processing labs and DHIA centers may have different measuring and calibration methods. This makes it difficult to compare CP in milk from different laboratories!

Since infrared technology can measure MUN and TP and TP represents the nutritional value in milk and MUN represents efficiency of protein feeding of dairy cows, it seems reasonable that reporting MUN and TP would be more valuable than reporting adjusted CP values. By evaluating TP, MUN and milk volume, some assessment of feeding may be made for groups of cows within a herd.

Casein, lactalbumin, and lactoglobulin are synthesized in the mammary gland (2,3). Primary blood constituents which serve as precursors include amino acids, glucose and acetic acid. Ninety percent of milk proteins are synthesized in the mammary gland from blood born constituents. Diet influences the supply of blood born constituents to the gland. Mastitis does not decrease synthesis of milk protein, but plasmin and proteases from neutrophils break down casein in the gland, reducing milk quality and true protein yield.

Diet can influence milk protein (3). Energy intake in the form of carbohydrate energy has been consistently correlated dietary with increases in milk protein (3,19). Emery (3) reported an increase in .015 units of protein content for each increase in Mcal net energy. Finely grinding forages or pelleting grain mixes have been associated with increased milk protein. Emery (3) also reported that milk protein increased .02% for each 1% increase in CP in the diet. Increases in energy intake associated with high fat intake consistently reduce milk protein (3). Rulquin and Scwab have demonstrated the importance of lysine and methionine as amino acids influencing milk volume and protein content in milk.

Based on experiments by Roseler and Baker (1,15), predictions of the effects of dietary changes may be made on milk constituents. Other authors have suggested that MUN and protein yield in milk would be effective tools for evaluating feeding programs (8,9,10,17,18). For Holstein cows producing 60 lbs of milk/day fed a well balanced diet we would expect milk to have the composition in Table 3 (2).

Table 3. Dietary factors influencing milk N yield and composition for Holstein cows producing 60 lbs of milk/day (from 2 based on data in 1 and 15).

Item	TP %	CP %	MUN mg/dl
Balanced Diet	2.90	3.10	11.3
Range	2.80-3.00	2.99-3.21	9.9-12.8
Increase Intake of Rumen Degradable Protein .5 lbs	2.90	3.11	13.0
Range	2.80-3.00	3.00-3.21	11.4-14.6
Increase Intake of Rumen Undegradable Protein .5 lbs	2.97	3.17	12.4
Range	2.85-3.08	3.05-3.29	10.9-14.2
Increase Ration Rumen Degradable Protein .5 lbs Decrease Undegradable Protein .5 lbs	2.83	3.04	11.8
Range	2.71-2.96	2.91-3.17	10.0-13.8

Evaluation of nitrogen supply to lactating dairy cows would have economic value to the producer and environmental value to the consumer. Over supply of DIP has been associated with reduced fertility in dairy cows (6,9,10,11,13,14,16). Evaluation of MUN relative to TRPRYD would allow assessment of efficiency of protein feeding and if protein supply being used in the diets had negative consequences for fertility. Additionally, excess MUN has no economic value to the producer or processor, particularly if milk is being utilized for cheese production. Excess MUN represents CP in the diet not utilized for productive purposes. Furthermore, excess nitrogen eventually contributes through urine and fecal output to environmental contamination. More efficient protein feeding, with the ability to monitor herds for dietary supply, would benefit the consumer through better nitrogen utilization on dairy farms.

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