Managing Nutrition for Optimal Milk Components

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Introduction

Feeding management practices on the dairy farm can have a major impact on the levels of milk fat and protein concentration in milk. Nutritional strategies that optimize rumen function also maximize milk production and milk components. However, there are several strategies that producers can use to enhance rumen function and the resulting milk components. For example, producers that use information from their dairy records can more critically evaluate their nutrition and feeding management programs. Utilization of herd and individual cow records allows identification of groups of animals, lactation number, days in milk, and economic assessment of these groups that contribute to loss of dollars when milk protein and/or milk fat is reduced in the herd. Nutritional strategies that impact milk components include adequate rumen degradable protein and adequate pounds of forage NDF in the diet especially for early lactation cows.

Factors that Affect Milk Composition

The impact of nutrition and nutritional changes in the ration can 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 can result 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. There are also many non-nutritional factors that can affect milk components such as genetics and environment, level of milk production, stage of lactation, disease, season, cow comfort, facilities, and age of the cow. We will discuss the main factors that impact milk components.

Normal Sources of Variation in Milk Composition

Genetics and Environment*:* The table below contains the breed averages for percentage of milk fat, true protein and fat to protein ratio. A change in milk composition using traditional breeding techniques occurs fairly slowly over many years. Heritability estimates for yield are relatively low at about 0.25 while estimates for milk composition are fairly high at 0.50. 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 over-looked. Genetic selection should be directed toward increasing fat, protein and nonfat solids yields. However, 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. 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

Breed	**% Fat**	**% Protein**	**Fat:Protein**
Ayrshire	3.85	3.15	1.22
Brown Swiss	4.04	3.37	1.20
Guernsey	4.51	3.37	1.34
Holstein	3.64	3.05	1.19
Jersey	4.60	3.57	1.29

Source: USDA-AIPL summary of herds on DHIA test during 2005

increase. 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 75 pounds to 85 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 75 pounds, protein production (yield) increases by only 0.07 pound per cow per day.

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. If cows go out on pasture in the spring, this generally reduces milk fat. Hot weather and high humidity decrease dry matter intake, and consequently energy intake, which in turn can reduce milk components. Heat stress is also known to decrease saliva production which in turn can affect the buffering capacity of the rumen. Reduced ruminal pH may reduce milk fat.

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*:* Mastitis has been shown to reduce fat and casein and increase 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 (> 500,000 somatic cells/ml) has longer coagulation time and form weaker curds than milk from cows with lower somatic cell counts.

Equipment: Milk fat can be reduced if cows are not completely milked out. In addition, over-agitation in the bulk tank can separate or churn milk fat. Finally, equipment effects such as improper vacuum, improper cooling, milk freezing, and improper sampling can also reduce milk fat.

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

Feed Intake and Peak Milk Production*:* Maximum feed intake minimizes negative energy balance during early lactation. As cows move into positive energy balance by consuming more energy than they are using, body weight is regained, losses in body condition are minimized and cows produce milk of normal fat and protein content. Increasing feed intake can improve milk protein by 0.2 to 0.3 units. This increase in milk protein percent may be caused by an overall increase in energy intake. Cows should reach peak milk production between 4 to 8 weeks postpartum, followed closely by peak dry matter intake between 10 to 14 weeks postpartum.

High producing cows eat 3.5 to 4.0 percent of their body weight daily as dry matter. If a herd is consuming less than 3.5 to 4.0 percent of body weight as dry matter, production of solids-corrected milk may be limited. A slow rise in postpartum feed intake lengthens the days to peak milk production and may reflect metabolic problems or obese cows. Research has demonstrated that fat cows have depressed appetites at calving compared to thin cows. This results in longer delays to peak milk yield. Body condition scores greater than 3.75 at calving can reduce dry matter intake 1.5 to 2.0 percent for every 0.25 body condition score over 3.75. Therefore, monitor feed intake and days to peak milk production to determine if cows are managed properly with adequate, but not excessive, body condition. Use of individual and or herd records allow producers to determine if changes in milk components are due to nutritional management strategies during the dry period or in early lactation.

Nutritional Influences on Milk Protein

It is much easier to change the fat content of milk than to change milk protein content. Milk protein in the mammary gland is synthesized mainly from amino acids in blood and are the primary precursors used to synthesize milk protein. Total milk nitrogen is approximately 76% casein, 18% whey and 6% non protein nitrogen. Protein production is usually limited by the amino acid that is in shortest supply in relation to the cow's requirement. That amino acid is called the "first-limiting amino acid". It is the missing link of the protein chain and when it is used up, protein production will be stopped. Energy, either from glucose or acetate, can also limit milk protein synthesis. The cow receives amino acids at the intestine from two primary sources. The rumen microbes provide 50-75% of the amino acids and rumen undegradable protein (bypass protein) provides the remainder. The efficiency of converting dietary nitrogen to milk protein by the cow is fairly low (25-30%). The cow uses many amino acids for the functioning of the gut, liver, and other tissues. This makes milk protein hard to change nutritionally. The balance of amino acids, rather than simply the amounts of individual amino acids, available for protein production in the mammary gland is also important for milk protein production.

Once we understand the amino acid supply better, it might become easier for nutritionists to accurately balance rations for amino acids and to predict and improve milk protein content and yield. More research is needed to help nutritionists accurately predict how much of each amino acid will be produced each day by the rumen microbes. More research would also help to predict how much of each amino acid from feed bypasses the rumen and is absorbed at the small intestine. Fortunately, we do know something about the rumen microbes and rumen bypass amino acid supply. Studies have shown that we can make improvements based on our current level of knowledge.

The Rumen Microbes: The first step to be taken in increasing milk protein is to take care of the rumen microbes. This means providing highly digestible forages, maximizing dry matter intake, avoiding sub-clinical acidosis, providing adequate amounts of soluble and degradable protein, and synchronizing rumen available carbohydrates and proteins on an hourly basis in the rumen. The amino acid profile of the rumen microbes is very similar to that of milk protein. Microbial amino acids are, therefore, easily and efficiently converted into milk protein by the cow.

Rumen Undegradable Protein: The blend of amino acids in the rumen undegradable protein will impact milk protein production. Corn and corn byproducts, such as distillers grains and corn gluten meal, are known to be low in lysine. Soy is known to be low in methionine. Animal proteins provide an amino acid package more similar to milk than corn and soy proteins. There are also individual bypass amino acids that are now being incorporated into feeds. The blend of rumen bypass amino acids should provide a profile of amino acids that complements the microbial protein made in the rumen. The goal is to combine the two sources of amino acids to make an intestinal amino acid supply similar to that needed for milk protein production. Most studies with supplemental bypass amino acids increase milk and milk protein yield in early lactation but increase milk protein content (%) in late lactation. Later in our discussion we will give an example of how paying attention to the metabolizable protein and amino acids needs of the cow can help make her use the protein she consumes more efficiently.

Carbohydrate Sources: Energy is needed for maintaining milk protein production. In early lactation, increased energy seems to stimulate both milk and milk protein production with little effect on the percentage of protein in milk. Later in lactation, energy does increase the concentration of protein in milk to a certain extent. Some of this response in milk protein may be due to the extra glucose and acetate available at the udder but added energy may more importantly cause an increase in microbial protein synthesis that increases amino acid supply at the udder. Studies have shown that feeding more rumen available carbohydrate can increase milk protein production. However, matching ruminal energy fermentation with the various protein fractions can also be effective in improving nitrogen (N) efficiency. There are substantial differences among starch sources and within grains due to processing, in the rates of energy release in the rumen. Ruminal digestibility of starch has been shown to be decreased from 70% with ground corn to 54% with coarsely rolled corn. Additionally, it has been shown that replacing some of the dietary starch with rapidly fermenting sugars can enhance ruminal capture of degraded N and impact milk fat and protein content of milk.

Effects Due To Fat Feeding: Excessive amounts of dietary fat have been shown to decrease milk protein production but the reason for this is still unclear. Fat substitution for ruminally available carbohydrate may depress microbial protein synthesis and thus, decrease the amount of amino acids available at the udder. Fat may also inhibit the growth of certain microbes directly. A limited amount of evidence suggests that excessive lipids can alter the way an animal processes and uses amino acids. Some nutritionists recommend adding 1% unit more rumen undegradable protein for each 3% added fat in a ration.

Nutritional Influences on Milk Fat

Short-chain fatty acids are made in the udder from short-chain volatile fatty acids, primarily acetate and butyrate, produced from the fermentation of fiber in the rumen. In addition, some short chain fatty acids in milk are made from beta-hydroxybutyrate circulating in the bloodstream. Long-chain fatty acids are not made in the udder but, instead, come from dietary fatty acids, the bodies of the rumen microbes, and the fat from the cow's back. The longer chain fatty acids in milk are directly extracted from circulating fatty acids in the blood. The short-chain and long-chain fatty acids are combined (about 50/50) to form milk fat.

The rumen microbes saturate 60-90% of the unsaturated fatty acid bonds of fats coming into the rumen. Fully saturated fatty acids or monounsaturated fatty acids with trans configuration (hydrogen atoms on either side of the double-bond rather than on the same side of the double-bond as in cis configuration) may escape from the rumen. Increased amounts of these trans fatty acids at the intestine are correlated with low milk fat syndrome. It is speculated that the mammary synthesis of fat from short-chain VFA's is inhibited by the trans fatty acids.

There are a number of reasons for an increase in the amount of trans fatty acids arriving at the cow's intestine. When cows are fed diets containing large amounts of rumen available unsaturated fatty acids, more trans fatty acids will escape the rumen. The rumen escape of trans fatty acids increases when cows experience rumen acidosis. The decrease in the rumen acetate:propionate ratio seen with rumen acidosis is a sign of a change in rumen fermentation which also increases the rumen escape of trans fatty acids and decreases milk fat concentration.

About 50% of milk fat is made from short-chain fatty acids, specifically acetate and butyrate. These are primarily made in the rumen from the fermentation of fiber. Good fiber fermentation is the result of feeding highly digestible forages and byproduct feeds, controlling rumen pH, controlling the levels of rumen available fats in the ration (<5%), and providing adequate amounts of rumen available nitrogen and amino acids. Usually, dietary fats are supplemented to meet the cow's general energy requirements. Often when supplemented, they increase milk fat synthesis but also increase milk yield, causing no change in milk fat content.

Limiting the Products Which Inhibit Milk Fat Synthesis: Rumen available unsaturated fatty acids primarily come from plant or fish sources. Fats in whole seeds, like whole soybeans and whole cottonseed, are slowly available in the rumen. These slowly available unsaturated fatty acids will usually be completely changed to saturated fatty acids before they leave the rumen. But, if the rumen environment is compromised or if large amounts of the whole seeds are fed, the fats may leave the rumen as partially saturated trans fatty acids that can lead to milk fat depression. If vegetable oils are fed, expect some of it to leave the rumen as trans fatty acids and potentially impact milk fat synthesis.

Milk Fat Depression vs. Low Milk Fat: There can be many causes of metabolic alterations on milk fat and therefore understanding the terminology my help you identify why butterfat in your herd or groups of cows is impacted.

Milk fat depression:

- Weight gain
- Excessive grain intake (>2.5% of BW) and/or fat
- Fat test < 3.0%; Protein % higher than fat
- Primary cause due to abnormal rumen function

Low milk fat test:

- Thin cows; Low dry matter intake
- Fat test 2.5 to 3.2%
- Protein to fat ratio near normal (1.14)
- Low peak milk yield
- Generally cows < 120 DIM
- Shortage of energy or ration imbalance

Effects of Acidosis On Milk Components: Subclinical, or chronic, ruminal acidosis is best described as a syndrome related to a fermentative disorder of the rumen. Although it involves a lowering of ruminal pH below pH 5.5 to 5.6, it is not adequate to define ruminal acidosis as being caused by low ruminal pH. The length of time pH is low and the number of bouts below 5.5 is even more critical. In most cases these ruminal problems can typically be traced to feeding management, the ration such as highly digestible carbohydrates, underfeeding of effective fiber, or all of the above.

One of the most common causes of acidosis occurs when switching from a high fiber to high concentrate diet that is rich in fermentable carbohydrates (starches and sugars). Large amounts of starch and sugar stimulate bacteria that make lactic acid. In this instance, bacteria that normally use lactic acid cannot keep up with production. The amount of acidity in the rumen is measured by pH readings. The optimal rumen pH should be between 6.0 and 6.2, but there is daily fluctuation below this level even in healthy cows. As the rumen pH drops below 6.0 fiber digestion is depressed. Because the end products of fiber digestion are used for milk fat synthesis, a drop in milk fat test is a sure sign of acidosis. In addition, the accumulation of acid causes an influx of water from the tissues into the gut and thus a common sign of acidosis is diarrhea. If the rumen pH continues to decline and falls below 5.5, many other normal healthy rumen bacteria also begin to be affected. As lactic acid accumulates, it is absorbed and lowers the pH of the blood. High levels of acid in the gut can also cause ulcers in the rumen resulting in infiltration of bacteria into the blood that can cause liver abscesses. Endotoxins resulting from high acid production in the rumen can also affect blood capillaries in the hoof, causing them to constrict resulting in laminitis. Sub-acute acidosis is also characterized by cycling intake because animals eat less during times of distress, then if the rumen adapts, their appetite returns.

Another common cause of acidosis is diets that are too low in effective fiber or too small particle size. When animals do not chew their cud normally, lack of saliva (that contains a natural buffer) contributes to low rumen pH. Adequate particle size in the ration appears necessary to avoid low milk fat syndrome. Cows require fiber and forage to stimulate chewing activity and saliva production, both being necessary to maintain a proper ruminal pH and a healthy rumen. Studies have also shown that forages that are too fine may cause lower butterfat tests. A study done to examine the effects of forage particle size reported that cows fed shorter particle size alfalfa silage had depressed fat tests. Besides depressed fat tests, finely-chopped forages can cause metabolic disorders such as ruminal acidosis and displaced abomasum due to their ineffectiveness in maintaining the cow's chewing activity and rumen pH. Diets that predispose cows to ruminal acidosis also increase the risk of feet and leg problems. For example, laminitis is associated with ruminal acidosis. Cows that suffer from laminitis are going to spend less time eating since it is painful for them to stand on their feet. These cows would, therefore, experience a drop in dry matter intake and milk production.

Cows that have the opportunity to sort their rations are also candidates for ruminal acidosis. Estimating particle size distribution of rations fed as well as the refusals helps to identify if this may be a problem. If the particle size distribution on the top screen of the particle size separator of the ration fed is greater than 10% compared to the refusals, the cows are likely sorting their feed. Though adding straw to rations to assure adequate physically effective fiber for cows is a good feeding strategy it is critical that cows do not sort against the straw in the total mixed ration. The straw has to be small enough in particle size to prevent cows from sorting.

Recently, researchers at the University of Wisconsin have found that some mycotoxins can alter the metabolism of lactic acid causing it to build up and cause acidosis. This may explain why acidosis and laminitis are also commonly observed when mycotoxins are a problem.

Common factors leading to acidosis in dairy cattle:

- Diet too high in fermentable carbohydrates; starch (% ration DM) > 28%
- Concentrate:forage ratio >55%
- Too fast a switch from high forage to high concentrate
- Too fast a switch from silage to high levels of green chop forage
- Low fiber content in diet; < 30% NDF and < 19% forage NDF (% of ration DM)
- Diet composed of very wet and highly fermented feeds; >52% moisture

- Over mixed TMR resulting in excess particle size reduction; > 20% in pan
- Unusual particle size distribution: 10% > on top screen; >20% on bottom screen; uneven distribution in the middle screen(s)

How can you tell if your cows have acidosis? Observe cows for these symptoms:

- Low milk fat test; < 3.0 to 3.3%
- Low milk protein
- Sore hooves; laminitis
- Cycling feed intake
- Diarrhea
- Limited cud chewing (<50% of cows lying down not chewing their cud)
- Reduced milk production compare to what the ration should support
- Feces in the same feeding group varies from firm to diarrhea
- Feces foamy, contains gas bubbles
- Appearance of mucin/fibrin casts in feces
- Increase in fiber particle size (> 0.5 inch) in feces
- Appearance of undigested, ground (≤ 1/4 inch) grain in feces
- Reduced feed efficiency

There are long term effects on both milk fat and milk protein due to acidosis. One incidence of acidosis in early lactation can reduce components for over three months.

Producers are paid for both for butterfat and protein. If components are reduced first attention is turned towards nutrition and feeding management as the culprit. Remember that low components can be due to inadequate energy in the diet, not enough feed being provided to the cows at the bunk, or an imbalance of carbohydrate fractions. Forage quality can severely impact the amount of energy cows are being provided in a ration. Therefore, in addition to doing a forage test when new forages are harvested and fed consider having the lab do a digestibility measure of the forage as well. It can provide additional information that might shed light on whether lowered milk fat is due to highly fermentable carbohydrates in the ration or inadequate energy provided to the cows stemming from low forage quality.

Applied Nutritional Strategies for Feeding Dairy Cows That Can Impact Milk Components

Improvements in Nitrogen Efficiency Impacts Milk Components: Protein tends to be overfed in rations either deliberately through ration formulation or due to inadequate monitoring of feed management practices. Protein nutrition is challenging because there are various N fractions, especially with ensiled feeds that add complexity when formulating rations and balancing them with carbohydrates. Excess protein fed results in increased N excretion. This is both an air and water quality concern. However, it is also an animal concern as excess N feeding reduces N efficiency and thereby impacts milk components.

There are several strategies to improve a farm's nutrient balance. A key factor is improving forage quality. This will allow more farm raised feeds to be fed and minimize the amount of purchased N (and P). Ammonia emission is a very important environmental issue. It can be released directly or indirectly from the degradation of proteins, which may occur within the soil or in the digestive system of the dairy cow and during manure storage. Ruminants excrete N in their urine and feces. The urea in urine, which in the presence of the enzyme urease found in the fecal material, rapidly decomposes to form ammonia. Ammonia is a very reactive compound and atmospheric ammonia can negatively impact the environment through several pathways. The regulations and environmental issues related to excess nutrients is real. Dairy producers are faced with implementing whole farm strategies that address these concerns. However, practical solutions are needed in order for the dairy industry to survive. It is possible to adjust silage based feeding systems to improve N efficiency of the dairy cow as well as maintain milk volume and components.

Forage Quality: There are numerous feeding strategies that can be implemented to improve nutrient efficiency. Improving and maintaining high quality forage is the key to developing a sound ration program. Forage quality and how animals perform on those forages is more than just entering a few numbers in a ration formulation program. How the dairy cow utilizes ensiled forages is influenced by growing environment, cutting date, moisture content and management practices at harvest, storage and feed-out (mycotoxins and spoilage problems). In addition to these factors, the cow's size, amount of dry matter consumed and the amount of forage in the diet affect rate of passage and digestibility of the forage. Emphasis is always placed on how forage nutrients will be utilized in the rumen environment, however post ruminal digestion should not be overlooked as a critical component in dairy nutrition.

There are numerous nutritional interactions occurring in the rumen. It is unrealistic to assume one value or values can adequately predict how efficiently an animal will utilize nutrients. Many forage testing labs are offering fiber digestibility testing. One weakness of this one value is that it explains only extent of feed digested for a single nutrient over a given time period, i.e. 24 hrs, 30 hrs, 48 hrs. However, measuring the rate at which forages are digested can provide important information. Having rates for key nutrients can help nutritionists develop feeding strategies to make cows more efficient. Consider the possible scenarios (rate of digestion) that can occur when feeding haycrop silage and corn silage:

Fast Fiber	Fast Starch	Fast Protein
Fast Fiber	Slow Starch	Fast Protein
Fast Fiber	Fast Starch	Slow Protein
Fast Fiber	Slow Starch	Slow Protein
Slow Fiber	Fast Starch	Fast Protein
Slow Fiber	Slow Starch	Fast Protein
Slow Fiber	Fast Starch	Slow Protein

Slow Fiber		Slow Starch		Slow Protein

Each scenario would require a different approach. For example, if fiber and starch are degrading at similar rates, then no special ration adjustments may be warranted. If starch degradability is slow along with fast fiber and protein, then altering starch particle size (fine grind vs. coarse grind) may be required. If fiber digestibility is slow, a more readily degradable fiber source may be needed. The same strategy matching carbohydrate to protein rates is just as important. It is easy to see why formulating rations is challenging. Many times nutritionists do not have access to detailed information on forages that would help explain animal response to various feeding strategies.

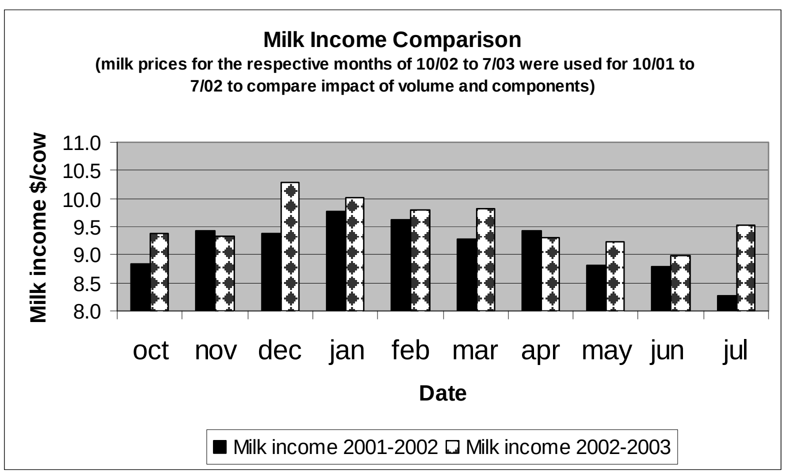
Several feeding strategies have been evaluated at the Penn State Dairy Complex over the past years. The question has been “Can lower protein diets be fed on various forage diets while improving N efficiency and maintaining or improving animal performance?” The various rates of carbohydrates and protein were taken into consideration when diets were formulated. The Dairy National Research Council 2001 (NRC) and Cornell- Penn- Minor (CPM) were the models used to evaluate the diets.

Feeding strategy 1 – Heavy corn silage diet: Historically, rations for the Penn State Dairy Herd had been formulated to the industry standard of 17.5 to18% crude protein on a dry matter basis for a one-group total mixed ration. The average production of the herd when fed the higher protein diet was 76 to 79 pounds on a 3.5% fat corrected basis. The table below shows the ration formulation for the 18% and 16% protein diets. The corn silage analysis was 37% dry matter, 8.8% protein, 41.7% neutral detergent fiber, 42.4% non-fiber carbohydrate and 0.74 net energy of lactation. Based on the forage quality and using CPM (ration formulation software), the scenario assumed to be most reflective of the forage ration was: “Slow Fiber Fast Starch Fast Protein”. To complement this feeding scenario coarsely ground corn grain was used to complement the fast starch. Protein sources with a balance of ruminal degradable and undegradable were used. Diets were formulated to closely meet the needs of the cow for metabolizable protein, rumen degradable protein and the proportion of lysine and methionine in metabolizable protein (NRC, 2001).

	18% CP	16% CP
Corn silage	25.6	26.5
Alfalfa silage	14.8	14.6
Hay	9.6	3.2
Cottonseed hulls	-	6.7
Shelled corn, coarse ground	14.2	20.3
Cookie meal	6.8	6.8
Liquid sugar (dextrose)	4.0	4.0
Distillers grain	5.0	1.7
Wheat midds	4.9	-
Heat treated soybean meal	4.9	1.6
Canola meal	4.0	6.7
Fish meal	0.4	-
Roasted soybeans	4.6	6.0
Min-vitamin mix	1.2	1.9

In addition to protein, the source and types of carbohydrates are just as important. The balance between sugar, starch and soluble fiber is essential for a healthy rumen. Formulating rations for protein and carbohydrate fractions to improve N efficiency is an important concept; however, what is an achievable goal and is it economical? Feeding strategies that improve nutrient efficiency are more than likely to happen if there is a positive economic incentive. A tool that is available to producers to monitor the efficiency of feed N utilization by dairy cattle is milk urea nitrogen (MUN. The inputs required are body weight, milk production per cow, milk protein percentage, and MUN.

We improved N efficiency by 4.6% units when comparing the average values for the herd on the 18% to the 16% protein diets. In addition energy corrected milk increased from 78 to 84 lb of milk/d. The key to achieving improved N efficiencies are feeding cows closer to their requirement for protein, improve milk production and milk protein, and reducing MUNs. The figure below illustrates the change in milk income comparing animal performance on the 18% vs. 16% protein diet. Because milk price can fluctuate considerably from year to year, the milk income was standardized. Milk price for the respective months of October 2002 to July 2003 were applied to the same months in the previous year (18% protein diet). The lower protein diet resulted in improved components and similar milk production over the same time period. Eight out of the ten months showed improved milk income based on volume, fat and protein response to the lower protein ration.



Feeding strategy 2 – Heavy haycrop silage (grass versus legume): The chemical composition of grass and legume are distinctively different. Crude protein content is generally lower for grasses than legumes; however the composition of the crude protein differs. Grasses contain more non-protein nitrogen in soluble protein and legumes contain more amino acids or peptides in soluble crude protein. Feeding alfalfa silage as the sole forage for ruminants often results in diets with excessive protein that is poorly utilized. Among the strategies that have been applied to dilute alfalfa crude protein have been to partially replace dietary alfalfa with corn silage for lactating cows. As soluble N load is increased from legume sources this additional N load on the kidneys increases the energy needs of the cow. The added metabolic costs to the animal, inefficient capture of N as ammonia in the rumen, and the inefficient use of this N results in greater excretion of N and therefore reduced milk protein and potentially reduced milk fat.

In 2005 Penn State evaluated animal performance and monitored ammonia emissions on alfalfa and grass silage based rations. The objective was to formulate protein levels close to animal requirement and adjust the particle size of corn grain to evaluate effects on milk volume, milk components, N efficiency and ammonia emissions.

Ingredient	Alfalfa silage	Grass silage
	Dry matter pounds	
Alfalfa silage	16.5	---
Grass silage	---	13.4
Corn silage	16.5	13.4
Cottonseed hulls	5.7	0.45
Shelled corn (fine or coarse)	11.1	11.8
Cookie meal	1.13	1.37
Liquid sugar (dextrose)	3.0	2.45
Canola meal	1.95	1.22
Roasted soybeans	6.1	4.95
Heat treated soybean meal	2.0	2.35
Mineral mix	2.14	2.19

The spring of 2004 was extremely wet and it was a challenge to get good quality haycrop forage ensiled. The 1st cut grass silage (64% NDF and 61% NDF 48h digestibility) was extremely high in moisture and low in quality. The alfalfa silage was 2nd cutting (41% NDF and 50% NDF 48h digestibility). One hundred twenty cows, 60 on the alfalfa and 60 on the grass based diets were fed in a freestall barn. The 60 cows consisted of 1st, 2nd and greater lactation with an even distribution of early, mid and late lactation cows. The average days in milk ranged from 185 to 195 days throughout the 4 month trial (February to May). The alfalfa and grass silage based rations, using CPM are assumed to be the following:

Fast Fiber (alfalfa) – Fast Starch – Fast Protein
Slow Fiber (grass) – Fast Starch – Fast Protein

Diets for the alfalfa and grass silage based rations were formulated for similar nutrient densities. Dry matter intakes were greater on the alfalfa diet vs. the grass diet (66 vs. 54 lbs/d, respectively). The Income over feed costs was better for the alfalfa based ration compared to the grass based ration. The MUN averaged 10.3 mg/dl and 11 mg/dl over the four month period on the alfalfa and grass silage based diet, respectively. The resulting N utilization efficiency calculated was 38.0% and 34.6% for the alfalfa and grass based diets, respectively. The alfalfa N utilization efficiency is comparable to the high corn silage ration discussed under feeding strategy 1. One of the maintain objectives of balancing N for the ruminant is to minimize N excreted and the resulting emission of ammonia, which is an environmental concern. These two feeding strategies emphasize the importance of not only looking at milk yield, and or milk composition but the overall cost of production.

Animal performance results from the alfalfa and grass silage based TMRs.

Milk	Fat	Protein	ECM	DMI-Eff	IOFC
lbs	%	%	lbs		
96.2	3.94	3.02	100.4	1.51	$10.74
85.4	4.1	3.26	92.3	1.71	$10.74
Grass based diet					
84.3	3.91	3.07	87.9	1.66	$10.09

Note: ECM= energy corrected milk; DMI-Eff= dry matter intake efficiency.

Feeding strategy 3- coarse vs. fine ground corn: Feeding strategies that alter ruminal rate and extent of fermentation can impact the economic value of milk components. We conducted a study where the Penn State herd was changed from coarse ground corn to fine ground corn. The rations are shown below.

	2004	2005
	DM lbs	DM lbs
Alfalfa silage	6.98	7.32
West hay	2.01	2.11
Bunk CS	17.67	18.41
Fine corn	0.00	11.59
Coarse corn	8.60	0.00
Cotton hulls	6.28	6.51
Rst beans	4.65	4.09
Canola	3.49	6.06
Cookie meal	5.81	2.17
Sugar liquid	2.85	2.99
Heat treated SBM	1.51	1.16
Mineral	2.29	2.40

The tables below demonstrate that a simple change in fermentability of the starch in the ration increased milk yield and milk protein. Again the combination of type of forage, quality of forage, and the combination of various carbohydrate and protein fractions were balanced to closely meet the metabolizable protein needs of the cow.

2004	Fat, %	Protein, %	2005	Fat, %	Protein, %
Oct	3.62	3.06	Oct*	3.44	3.12
Nov	3.64	3.10	Nov	3.85	3.13
Dec	3.60	3.10	Dec	3.78	3.14
Average	3.62	3.08		3.69	3.13

*switched to fine ground corn the middle of Oct

DMI, lb/d	Feed cost	IOFC	DMI-Eff	ECM, lb/d	Corn	Cow #
62	$4.05	$10.79	1.5	93	Coarse	60
65	$4.26	$12.44	1.63	106	Fine	60

ECM = energy corrected milk

Conclusions

Rations can be developed that optimize both milk yield and components. This requires a focused approach towards forage quality, feeding management, and nutrition. By monitoring components routinely, reductions that may occur in either fat or protein can be addressed quickly such that components can be maintained or improved thereby enhancing the economic profitability of the dairy business.