ABSTRACT

Increasing the amount of grain and other concentrates and reducing the amount of hay and other roughages in a dairy cattle ration changes the normal pattern of ruminal fermentation, resulting in production of less acetic acid and more propionic acid in the rumen. Fine grinding and pelleting of the ration gives similar results. These changes of ruminal fermentation are accompanied by a depression in milk fat synthesis, a slight increase in milk protein synthesis, and an increase in body fat deposition.

High grain can affect adversely ruminal microbes and papillae lining the rumen wall, resulting in poorer feed efficiency, less milk production, and more metabolic disturbances at or near parturition.

Use of more grains and less roughages in dairy rations decreases the value of the cow as a converter of nonutilized forages and fibrous by-products into palatable and nutritious human foods, milk and meat. It also would increase the competition between cows and humans for available grain supplies if world population continues to increase.

Ruminant Digestive System

To understand the mechanism of milk fat synthesis, let us take a brief look at the digestive system of the cow. Cows are ruminants, which means that they have four compartments to their stomachs. The first compartment, the rumen, is like a large fermentation vat. Billions of microorganisms, both bacteria and protozoa, live in the rumen and are indispensable for the health and normal metabolism of the cow. The proportions of types of microorganisms in the rumen at any one time depend on the type of ration being fed to the cow. Some microorganisms thrive on high fiber feeds, such as hay, pasture, and silage, and others predominate when the cow is fed a more concentrated diet composed primarily of grains and low fiber by-products.

Much of the carbohydrate portion of the diet is converted to volatile fatty acids (VFA) by ruminal microorganisms. The VFA’s are absorbed from the rumen into the bloodstream of the cow and become her primary source of energy. The VFA’s also are important building blocks for milk fat and solids-not-fat (SNF).

The two VFA’s produced by ruminal microorganisms that have the greatest effect on milk fat synthesis are acetic acid and propionic acid. High fiber rations promote more production of acetic acid; low fiber rations result in production of more propionic acid (2). Acetic acid is one of the main building blocks of milk fat, whereas propionic acid is used for a variety of metabolic functions, including lactose (milk sugar) synthesis, energy for metabolic functions, and when in excess, for body fat deposition.

When a typical dairy ration is fed that contains about two-thirds roughages, such as hay or silage, and about one-third concentrates, such as grains and their by-products, acetic acid...
makes up about 60% of the total VFA's produced in the rumen. Propionic acid comprises about 20% of the total, and the acetic-propionic ratio is about 3:1, as shown at the top of Figure 1. When fed this type of ration, an average Holstein cow produces milk with about 3.7% milk fat. If the proportions of roughages and concentrates are reversed (one-third roughages and two-thirds concentrates), the proportion of ruminal acetic acid decreases to about 55% and propionic acid increases to about 25%, resulting in about a 2:1 acetic-propionic ratio, as shown in the middle of Figure 1. The typical Holstein cow fed this ration will produce milk with about 3.5% milk fat. Going a step further and grinding and pelleting the ration with one-third roughages and two-thirds concentrates, thus reducing the particle length of the ration fiber, acetic acid decreases to about 40% of the total VFA's produced and propionic acid increases to about 40%, resulting in a 1:1 acetic-propionic ratio. Milk fat percentage from cows fed this ration may drop to 2.5% or less, as shown at the bottom of Figure 1.

Milk from cows fed a fat-depressing diet usually has slightly higher milk protein and SNF percentage. However, this increase in SNF is small compared with the decrease in fat test, being of the order of about .1 to .2%. Therefore, current milk pricing systems do not encourage this type of feeding program.

Metabolic Problems

Even if economics favored production of low fat milk, there are other problems encountered when a low fiber ration is fed to dairy cows, particularly if grains make up a large proportion of the ration. Grains are high in starch. One of the intermediate compounds in the fermentation of starch to propionic acid is lactic acid. If cows consume large amounts of readily fermentable carbohydrates, such as starch from grains, beyond the fermentative capacity of the microorganisms in the rumen, glucose accumulates in the rumen and can lead to rapid growth of lactic acid-producing bacteria. When more lactic acid is produced than can be used by ruminal microorganisms, ruminal acidity increases and many of the normal ruminal protozoa and bacteria are inhibited or killed. This condition is called lactic acidosis and may cause cattle to stop ruminating and go off feed. Some spontaneously recover after a few days, but acute cases can lead to death through hypotension and respiratory failure.

Cattle that do not reach the acute stage of lactic acidosis still may suffer health problems and decreased milk production. The high acidity in the rumen adversely affects the papillae which line the rumen wall. They are the main sites for absorption of VFA's from the rumen. Damage of papillae and the resulting scar tissue reduce VFA absorption, thus reducing milk production and efficiency of feed utilization. Feeding a buffer such as sodium bicarbonate tends to stabilize rumen acidity and prevent lactic acidosis (3). This treatment also reduces the amount of milk fat depression that occurs when cows are fed low fiber rations.

Besides the possible problem of lactic acidosis, low fiber-high concentrate rations that decrease acetic and increase propionic acid production in the rumen tend to overfatten dairy cows, particularly in late lactation when milk production is lower. Overly fat cows are more susceptible to a variety of metabolic disorders at or near their next parturition. These maladies, commonly referred to as the “fat cow” syndrome, include difficult calving, retained placenta, metritis, milk fever, displaced abomasum, and ketosis (5). In many cases, more than one of the disorders occur almost simultaneously, making it difficult to determine which is the primary problem and which is secondary. Feeding decreasing amounts of concentrates and more roughages as milk production declines in later lactation, followed by

![Figure 1. Effect of ration on proportions of ruminal acetic and propionic acids and milk fat percentage.](Image)
practically an all roughage ration during the dry period, is the best preventive for the "fat cow" syndrome.

Fiber Requirement

High grain-concentrates (within reasonable limits) are needed by high producing cows because of their high energy requirements. They cannot consume enough feed to fulfill energy requirements when the ration is composed entirely of forages and other roughages. However, the National Research Council recommends a minimum of 17% crude fiber in the total ration dry matter for lactating cows to maintain normal rumen function, cow health, and milk fat percentage (6). In addition, many dairy cattle nutritionists require certain amounts of roughages and limit concentrates to certain proportions in dairy rations to assure that some of the ration fiber is in the form of coarse roughage. Finely ground or pelleted roughages would not count toward the roughage requirement. Experience has shown that dairy cows fed rations with at least 17% crude fiber and adequate coarse roughage have fewer health problems, a longer productive life, and more milk production than cows fed high concentrate-low fiber rations that cause depressed milk fat synthesis.

Protected Fats

Manipulation of the diet also can increase milk fat production. Recent studies at several institutions have shown that feeding "protected" fats (animal or vegetable fats encased in a formalin-protein outer coating) changes the fatty acid composition of milk fat and increases milk fat percentage (4). "Protected" fats are resistant to microbial action in the rumen and much of it passes through intact to the abomasum. The high acidity of the abomasum breaks down the formalin-protein covering, allowing the encased fat to be absorbed from the intestines. Evidently much of this fat is incorporated directly into milk fat. Thus, if a "protected" polyunsaturated fat is fed to a cow, she will produce milk with an increased proportion of polyunsaturated fatty acids. Butter made from this milk is soft when refrigerated, similar to margarine. It also is more susceptible to oxidative rancidity because of its unsaturated fatty acids.

Subsequent experiments using high whole cottonseed in dairy rations showed similar results to those with "protected" fats (7). Cows fed rations containing 15% and 30% whole cottonseed produced milk with progressively higher fat tests than control cows fed no cottonseed. Changes in fatty acid composition similar to those obtained from feeding "protected" fats were noted. Evidently, much of the fat in whole cottonseed, which is encased in a seed coat, escapes ruminal degradation and is broken down in the abomasum in a manner similar to the breakdown of "protected" fats.

A negative side effect from feeding high "protected" fats or whole cottonseed is a depression of milk protein content. Furthermore, most of the depression is in the casein fraction which is important in cheese making. The depression in milk protein is much smaller than the increase in fat test when "protected" fats and whole cottonseed are fed but is certainly in the wrong direction if a lower fat and higher protein milk is desired.

Feed Conversion Efficiency

A final factor that must be given consideration in contemplating changes in the ration for dairy cows is how the cow fits into the scheme of feeding a hungry world. Like other classes of livestock, the cow is not efficient in conversion of animal feeds to human feed. The average dairy cow converts only about 20% of the energy and 30% of the protein in her diet to milk energy and protein. Cattle are even less efficient in the production of meat. Consequently, it would be more efficient for the growing human population to utilize grains as a source of food rather than cycle these foods through livestock. Therefore, the cow's primary justification as a producer of human food is that she can convert great quantities of forages and fibrous by-products which have little or no nutritional value for human nutrition into very palatable and nutritious human foods, milk and meat. When these coarse feeds, not utilisable by humans, are supplemented strategically with varying amounts of grain and other by-product concentrates in accordance with the production potential of the dairy cow, the net efficiency of her conversion of energy and protein from the supplemental feeds increases to more than 100% (1). This is because a large
portion of the energy and protein is derived from the fibrous feeds humans cannot utilize directly. Furthermore, with high input costs, judicious use of concentrates to supplement the forage portion of the dairy ration may result in lower consumer prices for milk and dairy products. But to use these supplements in greater amounts to manipulate milk components places the cow in more direct competition with humans for existing grain supplies. This competition is likely to become a more critical factor unless the world's population growth is brought under control.

REFERENCES