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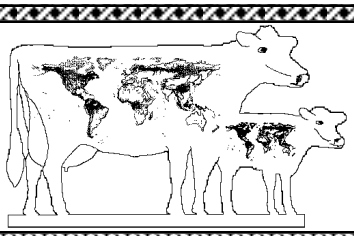

Dairy Essentials

19) MILK COMPOSITION AND NUTRITIONAL VALUE

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WHAT IS MILK?

Milk is the normal product of mammary gland secretion. The average composition of milk from cows and buffalo is presented in Table 1. Milk is a complex, nutritious product that contains more than 100 substances that are either in solution, suspension or emulsion in water. For example:

- Casein, the major protein of milk, is dispersed as a great number of solid particles so tiny that they do not settle, but remain in suspension. These particles are called micelles, and the dispersion of the micelles in the milk is referred to as a colloidal suspension;
- The fat and fat soluble vitamins in the milk are in the form of an emulsion; that is, a suspension of small liquid globules that do not mix with the water in milk;
- Lactose (milk sugar), some proteins (whey protien), mineral salts and other substances are soluble; that is, they are entirely dissolved in the water in milk.

The casein micelles and the fat globules give milk most of its physical characteristics, and give taste and flavor to dairy products such as butter, cheese, yogurt, etc. The composition of milk varies considerably with the breed of cow, stage of lactation, feed, season of the year, and many other factors. However, some relationships between constituents are very stable and can be used to indicate whether any tampering with the milk composition has occurred. For example, a milk of normal composition has a specific gravity that varies normally from 1.023 to 1.040 (at 20°C) and a freezing point that varies from -0.518 to -0.534°C. Any alteration, by addition of water for example, can be easily identified because these characteristics of milk will no longer be in the normal range.

Milk is a highly perishable product that should be cooled to about 4°C as soon as possible after collection. Extremes of temperature, acidity (pH) or contamination by microorganisms can rapidly decrease its quality.

Table 1: Composition of milk from different species (amount per 100 g)

Nutrient	Cow	Buffalo	Human
Water, g	88.0	84.0	87.5
Energy, kcal	61.0	97.0	70.0
Protein, g	3.2	3.7	1.0
Fat, g	3.4	6.9	4.4
Lactose, g	4.7	5.2	6.9
Minerals, g	0.72	0.79	0.20

MILK AS FOOD FOR HUMANS

Water

The nutritional value of milk as a whole is greater than the value of its individual nutrients because of its unique nutritional balance. The amount of water in milk reflects that balance. In all animals, water is the nutrient required in the greatest amount and milk does supply a great amount of water—it contains approximately 90% water.

The amount of water in milk is regulated by the amount of lactose synthesized by the secretory cells of the mammary gland. The water that goes into the milk is delivered to

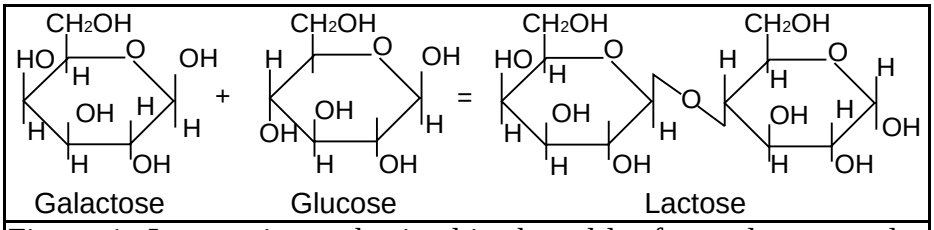

Figure 1: Lactose is synthesized in the udder from glucose and galactose.

the mammary gland by the blood. Milk production is very rapidly affected by a shortage of water and drops the same day drinking water is limited or unavailable. This is one reason why the cow should have free access to a plentiful supply of drinking water at all times.

Carbohydrates

The principal carbohydrate in milk is lactose (Figure 1). Although it is a sugar, lactose is not noticeably sweet to taste. The concentration of lactose in the milk is relatively constant and averages about 5% (4.8-5.2%). As opposed to the concentration of fat in milk, lactose concentration is similar in all dairy breeds and cannot be altered easily by feeding practices. The molecules from which lactose is made are found in much lower concentrations in milk: glucose (14 mg / 100g) and galactose (12 mg / 100g).

In a significant portion of the human population, the deficiency of the enzyme lactase in the digestive tract results in the inability to digest lactose. Most individuals with low lactase activity develop symptoms of intolerance to large doses of lactose, but the majority can consume moderate amounts of milk without discomfort. Not all dairy products contain similar proportions of lactose. The fermentation of lactose during processing lowers its concentration in many dairy products, especially in yogurts and cheeses. In addition, milk pre-treated with lactase, which minimizes the problems associated with lactose intolerance, is now available.

Proteins

Most of the nitrogen in the milk is found in the form of protein (Figure 2). The building blocks of all proteins are the amino acids. There are 20 amino acids that are commonly found in proteins. The order of the amino acids in a protein, which is determined by the genetic code, gives the protein a unique conformation. In turn, the spatial conformation of the protein gives it a specific function.

The concentration of protein in milk varies from 3.0 to 4.0% (30-40 grams per liter). The percentage varies with the breed of the cow and in proportion to the amount of fat in the milk. There is a close relationship between the amount of fat and the amount of protein in milk—the higher the fat, the higher the protein.

The protein falls into two major groups: caseins (80%) and whey proteins (20%). Historically, this classification followed the process of cheesemaking, which consists of separating the casein curd from the whey after the milk has clotted under the action of rennin or rennet (a digestive enzyme collected from the stomach of calves).

The behavior of the different types of caseins (α, β and κ) in milk when treated with heat, different pH (acidity) and different salt concentrations provide the characteristics of cheeses, fermented milk products and different forms of milk (condensed, dried, etc.).

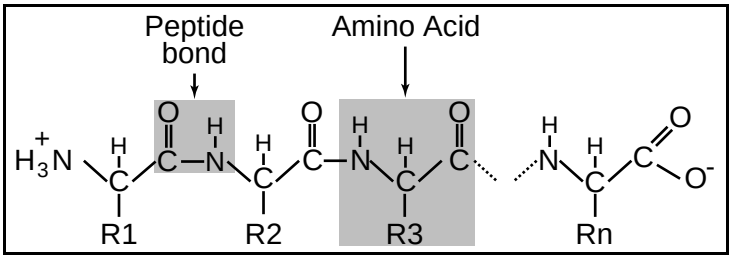

Figure 2: Structure of proteins (R1, R2, etc., are radicals specific to each amino acid. The number of amino acids in the caseins of milk varies from 199 to 209).

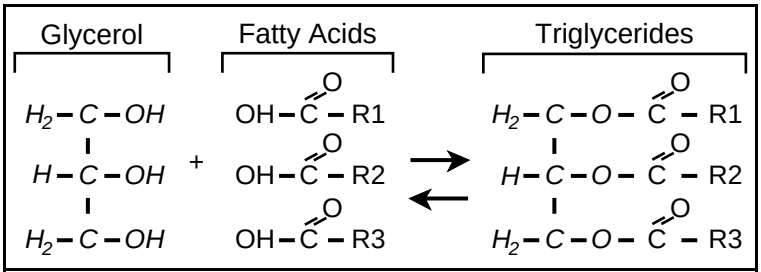

Figure 3: Structure of triglycerides (R1, R2, R3 represent the fatty acid carbon chains that give triglycerides their individual characteristics.)

Occasionally, infants or young children are allergic to milk because their bodies develop a reaction to the proteins in the milk. The allergy causes rash, asthma, and/or gastrointestinal disorders (colic, diarrhea, etc.). In cases of allergies, goat milk is often used as a substitute; however, sometimes hydrolyzed casein milks must be used.

Fat

Normally, fat (or lipid) makes up from 3.5 to 6.0% of milk, varying between breeds of cattle and with feeding practices. A ration too rich in concentrates that do not elicit rumination in the cow may result in milk with a depressed percentage of fat (2.0 to 2.5%).

Fat is present in milk in small globules suspended in water. Each globule is surrounded by a layer of phospholipids, which prevents the globules from clumping together by repelling other fat globules and attracting water. As long as this structure is intact, the milk fat remains as an emulsion.

The majority of milk fat is in the form of triglycerides formed by the linking of glycerol and fatty acids (Figure 3). The proportions of fatty acids of different lengths determine the melting point of fat and thus the consistency of the butter derived from it. Milk fat contains predominantly short-chain fatty acids (chains of less than eight carbon atoms) built from acetic acid units derived from fermentation in the rumen. This is a unique feature of milk fat compared with other kinds of animal and plant fats. The long chain fatty acids in milk are primarily the unsaturated (hydrogen deficient) acids, with the predominant one being oleic (18-carbon chain), and polyunsaturated linoleic and linolenic acids.

Minerals and vitamins

Milk is an excellent source of most minerals required for the growth of the young. The digestibility of calcium and phosphorus are unusually high, in part because they are found in association with the casein of the milk. As a result, milk is the best source of calcium for skeletal growth in the young and maintenance of bone integrity in adults. Another mineral of interest in the milk is iron. The low iron concentration in milk cannot meet the needs of the young, but this low level turns out to have a positive aspect because it limits bacterial growth in milk—iron is essential for the growth of many bacteria.

Table 2: Mineral and vitamin concentrations in milk (mg/100 ml)

MINERALS	mg/100 ml	VITAMINS	µg/100 ml[1]
Potassium	138	Vit. A	30.0
Calcium	125	Vit. D	0.06
Chloride	103	Vit. E	88.0
Phosphorus	96	Vit. K	17.0
Sodium	58	Vit. B1	37.0
Sulfur	30	Vit. B2	180.0
Magnesium	12	Vit. B6	46.0
Trace minerals[2]	< 0.1	Vit. B12	0.42
		Vit. C	1.7

[1] µg = 0.001 gram

[2] Includes cobalt, copper, iron, manganese, molybdenum, zinc, selenium, iodine and others.

MILK AS FOOD FOR THE CALF

Immune components

Milk contains proteins called immunoglobulins that are one of the calf's principal defenses against infectious organisms (viruses, bacteria, etc.). Concentrations of immunoglobulins are especially high in the colostrum, the milk produced immediately at the onset of lactation.

Immunoglobulins are not produced in the mammary tissue but are transferred directly from the blood serum into the milk. The calf can best adsorb the immunoglobulins immediately after birth, with the ability to absorb decreasing to near zero by 36 hours of age. This is because, in the first 12 hours of life, the calf does not produce appreciable amounts of hydrochloric acid in its stomach so the immunoglobulins are not damaged.

Colostrum should be given to the calf as soon after birth as possible. This will at least double the young calf's chances of survival. Colostral immunoglobulins are stable in the calf's bloodstream for 60 days, providing protection until its own immune system is functional.

Not only is colostrum of vital importance to the newborn calf, it also has no commercial value as it is not acceptable for commercial milk collection for human consumption. So, the milk from a cow that has freshly calved must not be included in the milk for sale for three to four days. Colostrum can be frozen and stored for administration to other calves.

COMPONENTS INFLUENCING MILK QUALITY

Cells in milk

Somatic cells in milk do not affect the nutritional quality per se. They are only significant as indicators of other processes that may be taking place in the mammary tissue, including inflammation. When somatic cells are present at rates of over half a million per milliliter, there is reason to suspect mastitis.

Undesirable components in milk

Milk and milk products are perishable foods. High standards of quality throughout the entire dairy processing industry are required to enhance and/or maintain the consumers' confidence, and to make them decide to buy dairy products. The milk leaving the farm must be of highest nutritional quality—unaltered and uncontaminated. Here is a partial list of the most common undesirable substances found in milk:

- Additional water;
- Detergents and disinfectants;
- Antibiotics;
- Pesticides or insecticides;
- Bacteria.

The vigilance of producers in following instructions for the use of chemicals, as well as good milking, cleaning and storage procedures are not only essential to their own success, but also to the success of the dairy industry as a whole.