Cow's milk

Introduction

Milk and other dairy foods were recognized as important foods as early as 4000 BC, evidenced by rock drawings. In Egyptian tombs dating back to 2300 BC remains of cheese were found. Writings by Marco Polo describe the drying of milk and drinking of fermented milk in China (1275). During the Middle Ages, milk and dairy products were important foods throughout Europe.
In North America, milk and milk products were introduced with the arrival of the Europeans and the first herd was established in 1600. With the Industrial Revolution fresh milk became available to a large population. As a result of continued advances and improvements in dairy industry over the years, today a wide variety of milks and other dairy products is available.

Mammals: feeding the young with breast milk

Milk is secreted by the mammary glands of *mammals* for their young babies; there is no difference between animals and humans.
The mammary gland ends in a nipple that has one or more openings and in this way the young can suckle.
Man has interfered with this process. A young calf is taken away from its mother and raised on artificial milk whilst the milk of the mother is removed by a milking machine. This happens especially with cows and to a lesser extent with goats and sheep.
Over many centuries the cow has been bred for the *amount* and *composition* of its milk. This breeding policy combined with a planned food composition has led to enormous improvements in productivity.

Not every *mammal* has the same number of babies. Nature has solved this problem by giving the different species of mammal a different number of nipples. For example, a sow (female pig) has 12-16 nipples with three openings on each, while a cow has 4 nipples, each with one opening. A woman has 2 nipples each with many openings. This may suggest that a woman is not 'built' to have more than two children at a time.

The composition of milk

Since cow's milk is commonly used, this milk is used as a basis for these training chapters. Cow's milk is (of origin) a natural product intended to provide the calf with all necessary nutrients. To ensure good growth and development.

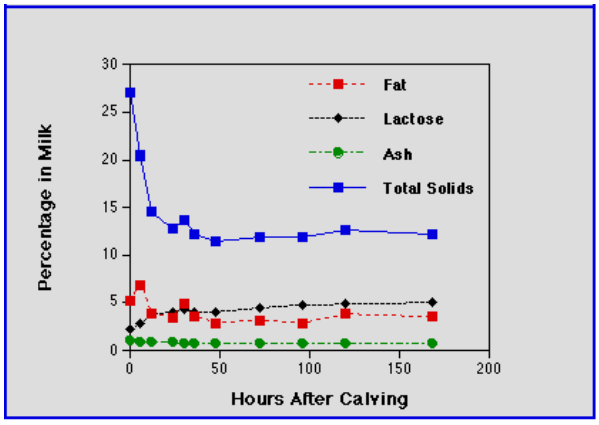
Average composition cow's milk

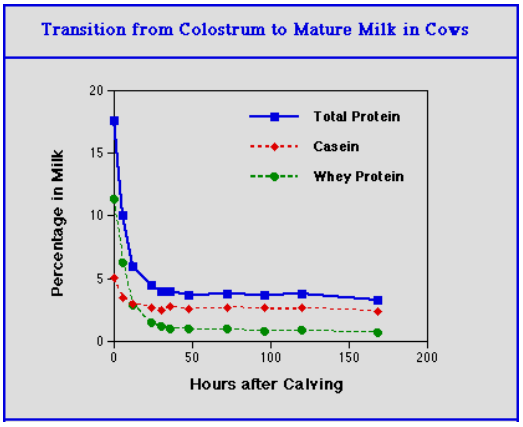
Nutrient	%	Energy%
Protein	3.4	21
• Casein / whey protein	80 / 20	-
Fat	3.7	50
Carbohydrates (lactose)	4.8	29
Minerals	0.8	-
Water	87.3	

A varying composition
The composition of cow's milk varies widely and changes throughout the lactation period. This depends on e.g.:
- Individual variability (from cow to cow)
- Beginning of feeding versus end of feeding
- During the day and day to day variation

Food and condition of the cow as well as species have direct impact on the milk composition.

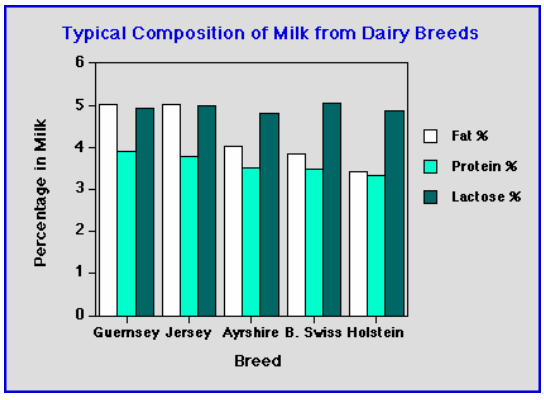
The major changes usually occur soon after the start of the lactation. The first milk is called *colostrum.* The composition of colostrum gradually changes to that of mature milk.

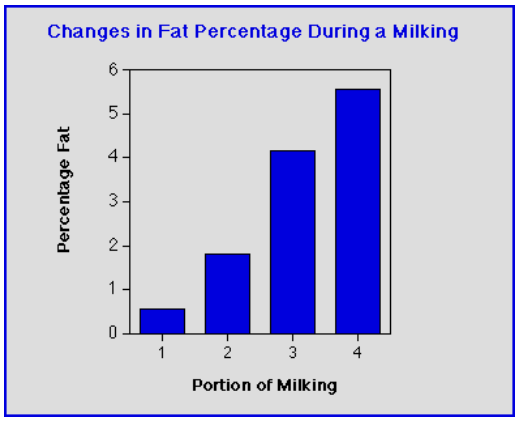




The total protein concentration decreases shortly after calving. This is due to a decline in the content of immunoglobulins; whey proteins which protect against micro-organisms from the environment. The lactose content increases during the initial hours post-calving. These general trends seem to be true for most other mammalian species, as well.

Breed differences in milk composition, especially fat and protein, have been the basis for part of the premium payments that dairy producers have received for the quality of the milk they produce.
The lactose content is fairly constant between breeds while fat varies extensively and protein varies somewhat. The milk composition also varies substantially among individuals of the same breed.





Even during a milk removal or milking, the composition can vary.

Fat is lowest in the fore-milk and gradually increases in percentage as the milk is removed. The last milk out of the gland is highest in fat content. It is important when taking milk samples from a cow for analyses that a well mixed sample is taken. This should represent the entire milk collected during a milking.

Variation in fat and protein content during the year
An increase/decrease of fat usually goes hand-in-hand with an increase/decrease in protein.

- The fat and protein content decrease during the first months of the year.
- When the cow is re-introduced in the meadow, both fat and protein content rise, after which they decrease again.
- Around August, fat and protein increase considerably, until November (highest level).
- After November both contents decrease again and this continues throughout the in-house period.

Because of its different protein content, the milk produced at the start of the lactation period is more sensitive to temperature treatment. That means that sterilisation processes are more difficult during this period.

Milk composition of different species
The milk composition of mammal species differs. This can be explained by the fact that mammals have a very different growth pattern. The composition of cow's milk, for example, is different from human milk. A calf doubles its birth weight in six weeks whereas for a human baby this will take about three months.

The milk composition of different species

	Protein (%)	Fat (%)	Lactose (%)	Minerals (%)
Woman	1.2	4.0	7.3	0.2
Cow	3.4	3.7	4.8	0.8
Antelope	6.9	1.3	4.0	1.3
Donkey	1.7	1.2	6.9	0.45
Bear (polar)	10.2	31	0.5	1.2
Bison	4.8	1.7	5.7	0.96
Buffalo (Philipp.)	5.9	10.4	4.3	0.8
Camel	3.7	4.9	5.1	0.7
Deer	10.4	19.7	2.6	1.4
Dolphin	10.4	14.	5.9	--
Elephant	4.9	15.1	3.4	0.76
Goat	3.1	3.5	4.6	0.79
Reindeer	10.3	22.5	2.5	1.4
Sheep	5.5	5.3	4.6	0.9

Ref.: Robert D. Bremel, University of Wisconsin and Handbook of Milk Composition, R. G. Jensen, Academic Press, 1995.

Protein: varies considerably, but not as much as fat varies among species. Ranges: 1% – 14%. Protein is positively linked with fat: if one is high, the other is also high.
Fat: ranges from 1% - over 50%. Aquatic mammals usually have high fat percentages.
Lactose: ranges from only a trace to about 7%. Some species have very little lactose in milk, such as the bear and kangaroo. Milk of these species often contains another sugar (milk from the kangaroo contains a tri-saccharide).

Nutrients in milk

Protein

Cow's milk (and dairy products) in general is an excellent source of high quality protein: containing all the essential amino acids in proportions resembling the body's requirements. Animal protein contains almost the same proportion of each essential amino acid as human protein. For this reason animal protein is also called *complete protein*; it has a high biological value (BV).

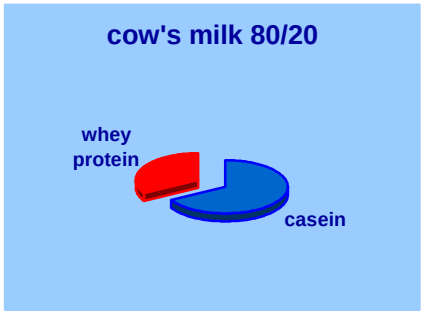
Protein in milk consists of a *(protein)-nitrogen fraction* and a *non-protein nitrogen fraction (NPN).* In cow's milk the NPN fraction contributes 2% of the total nitrogen fraction.

Protein in cow's milk

	Characteristics	Nitrogen fraction (*)	Non-protein nitrogen fraction (NPN)
Casein	Cow's milk: 80%	• α-casein • β-casein • γ-casein • κ-casein	• Various enzymes • Nucleotides • Urea • Free amino acids
Whey-protein	Cow's milk: 20%	• β-lactoglobulin • α-lactalbumin	
Other whey-proteins (smaller amounts), each with unique characteristics		• Serum albumin • Immunoglobulins (e.g. IgA, IgG, IgM) • Lactoferrin • Lysozyme	

(*) α = alpha, β = beta, γ = gamma, κ = kappa

Casein and whey-protein = 80/20
Of the total protein in cow's milk, about 80% is casein and 20% is whey-protein (serum protein). The amino acid composition of casein and whey protein is different. Compared to whey protein, casein contains less tryptophan (essential) and cysteine (conditionally essential).



- Casein
  As it exists in milk, casein is a salt of calcium. Casein is the fraction *that forms curds*. It is not coagulated by heat. It is precipitated (separated) by acids (action of acid in for example the stomach) or by an enzyme obtained from the stomach of calves (production of cheese). Casein does not denature easily; proteins denature when they lose their three-dimensional structure and thus their characteristic folded structure.
- Whey-protein
  Whey protein occurs in the whey fraction; the watery part of milk. Whey is the liquid remaining after milk has been curdled and strained. It is a by-product of cheese production and used for nutritional (and commercial) uses.

Cow's milk, especially colostrum, also contains (a small amount) protective substances:
- Immunoglobulins (antibodies): protect against micro-organisms from the environment.
- Lactoferrin: an iron-binding protein which inhibits growth of various micro-organisms in the intestine.
- Lysozyme: a natural antibiotic. It has both bactericidal and anti-inflammatory actions.

Fat
Milk fat contributes unique characteristics to the appearance, texture, flavour and satiability of dairy foods.
Milk fat exists in microscopic globules in an oil-in-water emulsion in milk. It consists mainly of tri-glycerides. The remainder is e.g. cholesterol and varying amounts of the fat-soluble vitamins A, D, E and K.

Milk fat contains a relatively high proportion of short-chain and medium-chain fatty acids (4 – 14 carbons in length). The composition varies somewhat according to the breed of the cow, stage of lactation, season, geographical location and feed composition.

Fatty acids in cow's milk

Saturated fatty acids (SAFAs)	62%	myristic, palmitic, stearic acid
Mono-unsaturated fatty acids (MUFAs)	30%	oleic acid
Poly-unsaturated fatty acids (PUFAs)	4%	LA, ALA, AA, EPA and DHA present in small amounts / traces
Remainder: minor types of fatty acids	4%	e.g. trans fatty acids (vaccenic acid)

Note:
LA (linoleic acid) and ALA (α-linolenic acid) are essential fatty acids.
- LA (parent of the ω-6 family) is converted via GLA (γ-linolenic acid = gamma-linolenic acid) by enzymatic help and via various other fatty acids into AA (arachidonic acid).
- ALA (parent of the ω-3 family) is converted via EPA (eicosapentaenoic acid) by enzymatic help and via various other fatty acids into DHA (docosahexaenoic acid).

Cholesterol is a normal constituent in milk, although milk contains relatively little cholesterol (<0.5% of milk fat). Because cholesterol occurs in the fat globule membrane, its concentration in dairy foods is related to the fat content. Cholesterol in the body is the precursor (fore-runner) of many important substances such as hormones and vitamin D.

Carbohydrates
Lactose (milk sugar) is the principal carbohydrate in milk. The word originates from the Latin word *lact* = milk. Lactose is a di-saccharide consisting of glucose and galactose.

Lactose (milk sugar) is digested, by lactase, into glucose and galactose and consequently absorbed. Not all lactose, however, is always digested. A part of the lactose passes

(unchanged) to the large intestine. Here, it is fermented by the bacterial flora. That means that also a part of lactose has a so-called prebiotic action:

- It stimulates the desired intestinal flora
- It influences the consistency of the faeces
- It stimulates the absorption of Ca, Mg, Zn and Fe

Furthermore lactose:

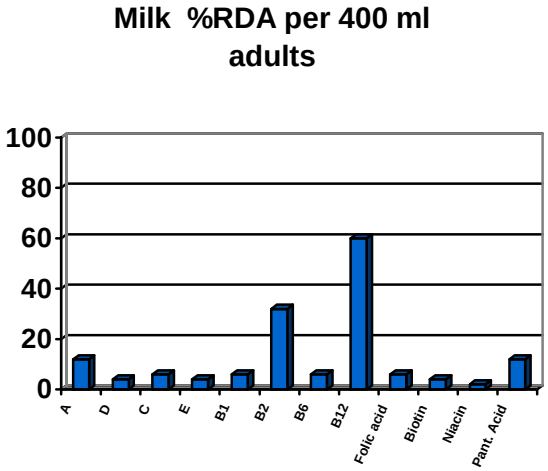
- Supplies galactose for a rapid glycogen production.

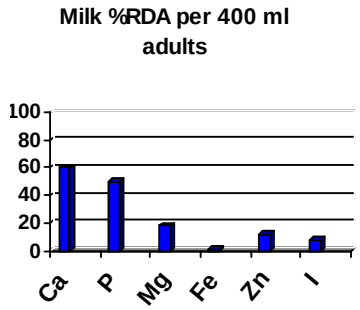
Sweetened condensed milk: protein turns brown upon heating with lactose (Maillard process). There are also a few bacteria capable of converting lactose: e.g. lactic acid bacteria. These bacteria are applied in the preparation of several dairy products (e.g. sour buttermilk, yoghurt).

Lactose intolerance occurs frequently, particularly amongst Asiatic and African communities. Lactose intolerance is a deficiency of the enzyme lactase. In case lactase is deficient, too much lactose (not digested) will be fermented in the large intestine, leading to e.g. flatulence, diarrhoea and cramps.

Vitamins, minerals and trace-elements

Cow's milk is a good source of vitamins, especially vitamin A, vitamin B2, B12 and pantothenic acid.
Because vitamin A exists in the fat portion of milk, lower fat and fat free (skim) milks contain less of this vitamin. For this reason, in some countries, low fat milks are fortified with vitamin A. This also applies to vitamin D.



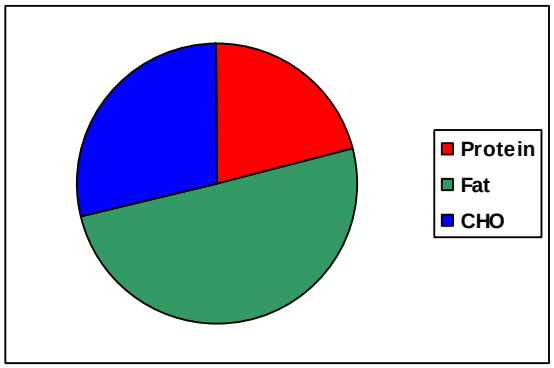


Cow's milk is a good source of especially calcium (Ca), phosphorus (P) magnesium (Mg) and trace-elements such as zinc (Zn) and iodine (I). Milk is low in iron (Fe).

Energy

100 ml of Cow's milk

• Protein	3.4 g	14 kcal	21 Energy%
• Fat	3.7 g	33 kcal	50 Energy%
• Carbohydrates	4.8 g	19 kcal	29 Energy%
Total		*66 kcal*	



Overview nutrients in cow's milk

Nutrient	
Protein • quantity • quality • casein/whey protein	 • 3.4 g / 100 ml • High BV: all essential amino acids in sufficient proportions = complete protein • 80/20
Fat • quantity • quality	 • 3.7 g / 100 ml • SAFAs = 62%, MUFAs = 30%, PUFAs = 4% (LA, ALA, AA, EPA, DHA: small amounts) Cholesterol: < 0.5% of milk fat
Carbohydrates • quantity • quality	 • 4.8 g / 100 ml • Lactose = milk sugar = di-saccharide
Vitamins	Especially: vitamin A, B2, B12, pantothenic acid
Minerals & trace-elements	Especially: Ca, P, Mg, Zn, I
Energy	66 kcal/100 ml • Protein 3.4 g 14 kcal 21 En% • Fat 3.7 g 33 kcal 50 En% • Carbohydrates 4.8 g 19 kcal 29 En%

The usage of milk

Milk is used in approximately 90% of all households. The largest part (75%) is taken directly as a drink. Important reasons for this are taste and nutrients. Milk is a healthy drink.
Even though consuming dairy is unnatural and problematic for many people, Canada's Food Guide recommends 2–4 servings per day, and the US Food Guide Pyramid recommends 2-3 servings. One serving is defined as 1 cup (236 ml) of milk, 2 slices of cheese or 3/4 cup of yogurt. The remainder is used for kitchen usage (preparation of desserts, etc.).

The components of milk can be extracted and used for the production of other foods.

Milk products