White Revolution: Dr. J. S. Pai

Milk is secreted by mammary glands to provide primary nutrition for newborn mammals. The early lactation, colostrums, also carries antibodies for the babies reducing disease risk in babies. Milk composition varies with species but contains good amounts of saturated fat, protein and calcium.

Milk is consumed by humans beyond infancy as food using milk of other animals like sheep, goats, water buffalo, camels etc. but most commonly cow milk. Milk from cow has been used to make cream, butter, yogurt, ice cream, cheese etc. Many food ingredients, additives and industrial products have also been prepared from milk e.g. casein, whey protein, lactose, condensed & powdered milk etc.

Indian Dairy Industry

India became the largest producer of milk a few years ago with the US and China being 2nd and 3rd largest producers. In 2006-07, Indian milk production including cow and buffalo milk, was over 100 million tonnes, roughly 15% of world milk production. It is set to become 111 million tonnes by 2010 with the growth rate of almost 4% per annum. In spite of such impressive production figures, the per capita availability (245 g per day) is lower than the world average (285 g per day). However, India is among the fastest growing markets for milk and milk products at 7.5% with a value of over Rs. 200,000 crores. The demand for value added products like cheese, yogurt (curd) and probiotic drinks is increasing at double digit rates.

Top Ten Milk Producers — 2005 (1000 tonnes)	
India	91,940
United States	80,264
China	32,179
Russia	31,144
Pakistan	29,672
Germany	28,487
France	26,133
Brazil	23,455
United Kingdom	14,577
New Zealand	14,500
World Total	**372,353**

As per one estimate consumer value of dairy products in 2005 was over Rs. 227,000 crores of which liquid milk was Rs. 83,000 crores, ghee Rs. 23,000, khoa/chhana/paneer Rs. 24,000, milk powder Rs. 4,700, table butter Rs. 770 crores, cheese/edible casein Rs. 975 crores, and other products including ethnic sweets, ice-cream etc. Rs. 9,100 crores. Of the total milk produced over 75% is sold as liquid milk of which organised industry handles only 18%. Private dudhwalas and other unorganised players sell 36% and about 46% is retained in rural areas.

India's emergence as world's leader in milk production, began around 1950's when young Dr. Kurien helped establish dairy cooperative in Gujarat now famous as Amul. Those efforts became responsible for steady growth of dairy production and Dr. Kurien is called the father of the White Revolution in India or also the Milkman of India. Today, there are tens of thousands of village cooperatives producing milk.

Today, India's largest agricultural crops rice (92 million tonnes) and wheat (75 mt) are behind milk production (over 100 mt). Although the price it fetches is more than rice and wheat and also farmers realise 60-70% of consumer price as against just 20% or so for fruits and vegetables, there are some problems of networking the procurement properly. Also the value addition will benefit the industry.

Milk Composition

Milk contains water (over 80 to 85%) in which fat globules are emulsified and kept stable by fat globule membrane made of phospholipids and proteins. Thus although milk contains significant amount of fat, it does not separate because these tiny fat globules (about 4 to 10 μm diameter) are kept separate from each other by these emulsifiers. However, agitation or churning will disrupt the membrane allowing fat globules to merge into larger particles that can separate and collect at the surface as cream or butter.

Homogenisation is done by passing milk under pressure through a small orifice, so as it emerges out, the globules experience sudden decompression and break into even tinier globules that will be extremely stable against agitation and this milk will not easily form cream layer.

Major portion of the protein is casein that is present as micelles or spherical aggregates of large number of protein molecules with diameters of about 0.1 μm. Colloidal calcium phosphate acts as a cement to keep the casein micelle intact. Besides Ca-phosphate, there are many interactions like hydrogen and disulphide bonds, hydrophobic and electrostatic interactions and other forces that keep

the stability. The stability of the micelle will be affected by certain other factors like salt content, pH, temperature and moisture that may try to destabilise it under unfavourable conditions.

There is a minor protein fraction called whey proteins that are soluble in water. They consist of globular proteins, mostly β-lactoglobulins and α-lactalbumins. There are also immunoglobulins present that confirm immunity against many diseases. Whey proteins are very heat sensitive. Milk proteins are of high biological value providing all the essential amino acids.

Milk contains a unique sugar, lactose. In nature lactose is found only in milk and very few plants. This along with fat, provides major source of calories. Besides there are vitamins and minerals and certain bioactive substances including enzymes. Nutrients present in cow's milk and comparison of milk of other species is given in tables.

Colour of Milk

White colour of milk is due to both tiny fat globules and very small casein micelles scatter the light. Skimmed milk having almost no fat looks slightly bluish as casein micelles scatter shorter wavelengths. Cows (especially Jersey and Guernsey) have good amount of carotene in fat contributing to yellowish colour to butter and creamy colour to milk. Buffalo milk fat contains very little carotene so the milk looks whiter and the butter is also white.
Although cow's milk is mostly consumed world over, Indians consume buffalo milk much more than cow's. Although goat milk consumption is also significant it is quite low compared to buffalo and cow. There are inherent differences in chemical and physical properties of the two milks as seen below.

Composition of Cow & Buffalo Milk

Constituent (%)	Cow Milk	Buffalo Milk
Water	86.50	83.18
Fat	4.39	6.71
Protein	3.30	4.52
Lactose	4.44	4.45
Total solids	13.50	16.82
SNF (Solids-non-fat)	9.11	10.11
Ash	0.73	0.80
Calcium	0.12	0.18
Magnesium	0.01	0.02
Sodium	0.05	0.04
Potassium	0.15	0.11
Phosphorus	0.10	0.10
Citrate	0.18	0.18
Chloride	0.10	0.07

These are only the average values. There are many differences that will be seen within these which may be due to breed, time & stage of milking, lactation period, season, feed, nutritional level, environmental conditions, health, age, exercise, medication and hormonal treatments etc.

Milk Composition – Different Species, per 100 grams

Constituents	unit	Cow	Goat	Sheep	Water Buffalo
Water	g	87.8	88.9	83.0	81.1
Protein	g	3.2	3.1	5.4	4.5
Fat	g	3.9	3.5	6.0	8.0
Carbohydrate	g	4.8	4.4	5.1	4.9
Energy	kcal	66	60	95	110
Sugars (Lactose)	g	4.8	4.4	5.1	4.9
Fatty Acids:					
Saturated	g	2.4	2.3	3.8	4.2
Mono-unsaturated	g	1.1	0.8	1.5	1.7
Polyunsaturated	g	0.1	0.1	0.3	0.2
Cholesterol	mg	14	10	11	8
Calcium	IU	120	100	170	195

Processing of Milk

As milk is highly nutritious, most microbes can grow in it and spoil it. Within hours it starts souring and all kinds of microorganisms including bacteria, yeast and mould will spoil and putrefy it unless it is processed and preserved using different processes such as thermal processing including pasteurisation, sterilisation, UHT processing etc., chilling, drying, converting to different products with longer shelf life among other things.

Thermal processing involves heating milk at a temperature where spoilage bacteria are killed. Although milk in cow's udders is sterile but as it is drawn, it gets immediately mixed with many bacteria commonly present in barn surroundings, especially the lactic acid bacteria. These grow extremely well in milk and produce lactic acid from lactose and cause the pH to drop. At pH less than 4.6, casein precipitates and milk curdles. When the process is done using desirable bacteria, curd or yogurt is formed, but when uncontrolled then undesirable bacteria and other microbes may grow causing spoilage along with acid production.

When milk is heated these bacteria are destroyed. When heating is done to kill all the bacteria rendering the milk sterile, the process is called sterilisation. This involves very severe heating. Commonly milk is pasteurised to specifically kill pathogens or disease causing microorganisms along with a large proportion of lactic acid bacteria as well. Since this process does not kill all the spoilage organisms, milk can spoil after cooling and keeping for some time when the surviving bacteria start multiplying and grow to a large number. Hence pasteurised milk is chilled and kept at refrigerated temperature as colder condition slows down their growth.

Pasteurisation process is named after its discoverer Louis Pasteur and may be carried out by heating milk at 71.7°C for 15 seconds using high temperature short time (HTST) process compared to earlier low temperature holding at lower temperature using longer heating time. As temperature is increased, the process time gets exponentially lower that not only saves time and cost but also there is less destruction of heat sensitive nutrients.

Sterilisation requires severe heating and mostly carried out in bottles or cans after the product is sealed. Once all microbes are killed, as long as no new bacteria are introduced, the product remains unspoiled for a long time although some chemical change may take place. A new process of sterilisation uses aseptic technology. Here the product is sterilised at ultra high-temperature (UHT) treatment generally about 130°C for a second or less, immediately cooled and without allowing microbes getting into the product, milk is packed aseptically into sterile containers and sealed, so the product remains sterile and long lasting. UHT process has even greater benefit of preventing the losses of nutrients and the product can be stored without refrigeration.

Fermented Miks

Original function of fermenting milk was to extend its shelf life. With this came many other advantages like improved taste and digestibility as well as producing a variety of products. Earlier fermentations occurred spontaneously due to indigenous microflora of milk namely lactic acid bacteria that produced lactic acid from lactose and typically suppressed spoilage and pathogenic organisms effectively.

Today the fermentations are controlled using specific starter cultures and controlled temperature. Examples of fermented milk products are acidophilus milk, kefir, koumiss, buttermilk, sour cream etc.

Common Milk Products

There is a large number of products that are made in many parts of the world. Initial efforts were to preserve the milk in different forms but then innovative variations were made to make different products with different consistencies, texture, colours and flavours using many ingredients and to be consumed at different temperatures. There are many milks including whole, skimmed (with different fat%), condensed, dried, evaporated, flavoured and milk shakes. There are many yoghurts like plain, fruit, low fat, flavoured, drinking etc. There are many cheeses including cheddar, swiss, cottage, cream, reduced fat, stilton, Cheshire, soft (brie), blue, mozzarella, whey cheese etc. There are different types of creams and butters and a large number of dairy desserts and sweets like ice creams, custard, pudding and a long list of Indian sweets including shrikhand, rasso golla, pedha, burfi, kulfi, etc.

Butter & Buttermilk

Butter is prepared by souring the cream that is separated from milk by cream separators. After souring the separation becomes easier and also there is flavour production especially the formation of diacetyl that gives characteristic buttery aroma. When the soured cream is churned, butter separates from the buttermilk which is a very nutritious beverage. It has very little fat as most is removed as butter, but it still has most of the other nutrients including protein, vitamins, minerals etc. Buttermilk can also be prepared directly from whole or partially or fully skimmed milk after fermentation. The resultant yoghurt can then be churned and one gets buttermilk with higher fat. Indian traditional lassi is prepared by adding sugar or salt along with spices to this.

Yogurt

Yoghurt is prepared by fermenting milk by bacterial cultures that convert some of lactose to lactic acid. This lowers pH giving it tart flavour and a semi-solid texture due to precipitation of proteins at the lowered pH. This product has been produced in many Asian countries including India for centuries using mixed cultures. In India it is called curd or dahi and usually uses cultures present in previous batch of curd. These cultures were natural flora that have been used over a long periods.

Industrially produced yoghurt uses pure cultures specially developed to produce lactic acid and good flavour quite rapidly and with consistency so production processes could be standardised. Most commonly *Lactobacillus bulgaricus* strains but others are also

used. The fruit and other ingredients including flavour and colour may be used to enhance the appeal. Manufacturers have started using other probiotic cultures including *Bifidobacterium* to add health benefits.

Cheese & Paneer

Difference between cheese and paneer is that while milk is fermented and enzyme rennet is added to curdle it for cheese making while lemon juice is added to heated milk and curdled it to make paneer. Also most cheeses are then ripened while paneer is simply pressed and cut into pieces. Cheeses use fermentation with lactic acid bactaria and also use rennet to hasten coagulation. The curd is then cut to drain the whey. Pressing is also used to hasten draining of whey. The drained curd is then milled to form smaller pieces.

Soft cheeses like cottage or cream cheeses are consumed without ripening. Other cheeses are ripened to make hard cheeses like Cheddar, Edam, Swiss etc. or soft cheeses like Camembert, Limburger etc. The ripening may be done by microbes and/or enzymes that will hydrolyse protein and fat. During ripening microbes grow and produce flavour substances. In Swiss cheese *Propionibacterium* grows and produces CO_2 what forms holes or eyes in the cheese along with the bittersweet flavour, while in Blue cheese, mould *Penicillium roquefortii* along with the characteristic blue-green colour it produces sharp flavour.

Ice Cream

This is a frozen dessert prepared using milk and cream along with flavourings and sweeteners. The mixture is stirred while cooling so ice crystals remain very small resulting in smooth texture. In most ice creams a lot of air is whipped giving ‘overrun’ making the product lighter and softer. There are many variants with flavours as well as with ingredients like fruits, nuts, other confectionery pieces like chocolate, candies, jellies, as well as coated and multiple variants. Some frozen desserts are made with vegetable fats instead of milk fat. One variation is ice cream with cone in which waffle cone is baked and in this ice cream scoops are put to conveniently eat with no other accessories like plate or spoon. This idea is further extended to ice cream sandwich. Now with all types of variants, there are hundreds of different types of ice creams available including Indian variant Kulfi. This product is not aerated so is much denser and harder.

Indian milk based sweets

Indians use mostly cow and buffalo milk for most sweets and these milks are more suited for certain applications than others. For example, qualities such as high total solids and fat content, superior whiteness and viscosity render buffalo milk suitable for making khoa, dahi, paneer, kheer, payasam, malai, kulfi, ghee and other traditional products. Cow milk yields a soft coagulum, making it suitable for preparation of chhana and its products such as sandesh, rasogolla, chumchum and rasmalai.

Buffalo milk also has more protein and fat. The coagulable proteins, caseins are much more in buffalo milk, so when milk is coagulated by heat and/acid, there is firmer and denser coagulum produced which is suitable for products like paneer, peda, burfi etc. Cow’s milk produces softer coagulum and gives a springy texture, which is more suitable for products like rasogolla, sandesh and rasmalai.

Indian milk sweets have been developed to preserve the nutritional goodness of milk and to extend its shelf life under high ambient temperature. Sweets are mainly prepared from three intermediate product bases: khoa (partially heat-desiccated milk), chhana (coagulated milk after draining of whey) and chakka (concentrated curd).

Khoa is a major intermediate product base for a variety of sweets. It is obtained by rapidly evaporating milk in shallow pans to a total solids content of about 70%. The product could be preserved for several days and is also used as a base for different kinds of sweets like peda, burfi, gulab jamun, etc. Another important base is chhana. It is obtained by acid coagulation of hot milk and draining out the whey. This product is used as an ingredient in different kinds of sweets, especially in the eastern region of India. Chhana based sweets are popularly called Bengali sweets e.g. rasogolla, rasomalai, rajbhog, khirmohan, sandesh, pantua etc. The third major intermediate base is chakka, popular in western India. It is a fermented product obtained from dahi (curd) and is used in a variety of Gujarati and Maharashtrian desserts. Whey is drained using cloth which removes most of the unfermented lactose. Sweets like shrikhand, mishti doi etc. are prepared by adding sweeteners like sugar and jaggery along with flavourants and colours.

Nutritional & Health Benefits

Milk is an excellent source of calcium and high quality protein along with many other nutrients including biotin, pantothenic acid, thiamine, folate, iodine, potassium, magnesium, selenium, among others. Calcium from milk is more bioavailable compared to certain vegetables like spinach that have calcium chelating agents.

Some studies have shown that consumption of low-fat milk reduces risk of hypertension, coronary heart disease, colorectal cancer and obesity. Overweight individuals consuming milk may have reduced risk of insulin resistance and diabetes type 2. Milk is a source of conjugated linoleic acid that has been shown beneficial against cancer and also lower cholesterol.

Lactose intolerance

This problem is more common in certain countries and ethnic groups where milk is not traditionally consumed in adult diet. In South America, Africa and Asia, over 50% people are intolerant to lactose whereas in Northern Europe and America, about 5% have this condition. In these people, lactase the enzyme needed to digest lactose is absent or present very little. Lactose intolerance causes symptoms like bloating and diarrhoea when a glass or two of milk or equivalent amount of milk products are consumed.

The lactose in milk goes through intestine without getting hydrolysed to glucose and galactose. Body can absorb these sugars but not lactose so the undigested lactose goes to large intestine where bacteria immediately start growing on them producing large amount of gas that causes the symptoms.

These individuals can have smaller amounts of milk without reacting. They can also consume cheese, buttermilk, fermented milks and yoghurt without any problems. Cheese contains much less lactose but yoghurt and other fermented products contain smaller but similar amounts of lactose as milk but still it is easier to digest for lactose intolerants. A small amount of lactose is converted to lactic acid but still yogurt contains about 4.7% lactose whereas milk contains about 5%. Possibly lactic acid bacteria help digest lactose. In the US and some European countries, milk treated with lactase is available. Such milk contains very little lactose and is safe for lactose intolerants.

Milk protein allergy

Unlike lactose intolerance, milk allergy can cause mild to severe reactions. It may cause skin rashes, itching, diarrhoea, vomiting, stomach cramps, wheezing, rhinitis, asthma and difficulty in breathing. In very few cases allergy can cause anaphylaxis which can be life-threatening. Allergy is commonly caused by certain proteins or allergens trigger formation of immunoglobulin antibodies that start the allergic reactions in the body. Unlike intolerances, extremely small amounts of allergens can cause allergic symptoms so sensitive individuals must totally avoid allergenic substances.

Cow’s milk allergy is common in infancy and is often outgrown by the age 3 to 5 years. In several countries, the prevalence of cow’s milk allergy among young infants is about 2%. There are also some hypoallergenic milk based formulas available for sensitive infants. Here the proteins are hydrolysed to very small peptides. As the allergens need to have certain size in order to be recognised by body’s immune system, very small peptides do not cause formation of antibodies responsible for triggering these symptoms.

Conclusions

India is the largest producer of milk and Indian food industry is showing rapid growth of many value added food products. Milk is a unique material that is both healthy and has many applications as ingredients in many different food products. Its industrial products like casein, whey protein isolate, caseinates etc. have further enhanced the possibility and usefulness. Indian consumers are showing keen interest in new products not just western food products like hamburger, pizza etc. that uses cheese and other dairy products, but also variants of traditional products. The future is quite promising for milk and products in India.

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