Review

Camel milk and its allied health claims: a review

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Summary. Camel milk is one of the most important milk among other mammal's milk due to its nutraceutical attributes. It has high concentration of iron which makes it panacea for those who have iron deficiency anemia. The salts present in camel milk has significant effect on human health. It is used for various diseases in urban areas of developing countries. It is a potential functional food. In urban areas of developing economies it is used for ascites. Camel milk is unique from other ruminant milk in terms of composition as well as functionality, as it contains high concentration of immunoglobulins and insulin. People with enervated immune system and those who are lactase-deficient can consume camel milk without any allergic response. Moreover, it is also used for potential therapeutic properties such as efficacy against diabetes and cancer as well as having anti-hypertensive properties.

Key words: camel milk, nutrition, functional food

Introduction

In Pakistan 0.8 million heads of camels are reared in the desert areas mostly in Sindh province, *Cholistan* (Punjab) and hilly areas of *Balochistan*. These animals are utilized mainly for transportation and much less for meat and milk. Although the buffalo milk is expected to be the major source of milk for the people of Pakistan, an ever spiraling demand of milk in summer season warrants study of milk from other species like camel. Average milk yield of camel ranges from 3.5 to 35.0 liter per animal per day with an average lactation yield of 4575 to 20675 liter (1). The major portion of this milk is used to feed their young ones, and rest of the milk is consumed by the owner as fresh or when just slightly soured or mixed with buffalo milk and sold to consumers in big cities.

Milk is the main source of nourishment for the newly born calves; it provides the entire nutritional requirements (carbohydrates, proteins, fatty acids, minerals, immune modulators and growth factors) required for growth and development of the body. In comparison to bovine varieties, camel milk whey contains a higher amount of anti-microbial factors such as lactoferrin, immunoglobulins and lysozyme (2). To the contrary, camel milk whey lacks beta lactoglobulin which is a main serum protein present in milk of other ruminants. Some other whey proteins which have been recognized in camel milk are α lactalbumin, serum albumin, peptidoglycan recognition protein and lactophorin (3).

Camel milk is unique from other ruminant milk in terms of composition as well as functionality; as it contains high concentration of immunoglobulins and insulin. It is high in vitamins (A, B-2, C and E) and minerals (sodium, potassium, iron, copper, zinc and magnesium) and low in protein, sugar and cholesterol (4,5). Vitamins present in camel milk have antioxidant activity and helpful in controlling tissue damage caused by harmful substances (6). In addition to that, camel milk has a high storage room temperature capacity as compared to milk from other animals (7).

Camel milk plays a significant role in human diet in arid countries and hot regions. Camel milk is just like the bovine milk in terms of its essential nutrients (2) and from ancient times it is being used for curing a number of diseases (8). In different areas of the world including Sudan, Russia and India, fermented and fresh camel milk have been used effectively for the treatment of wide range of diseases such as dropsy, asthma, leishmaniasis or kala-azar, jaundice and tuberculosis (9).

Camel milk is being used by the sick, the old and the very little ones because of the fact that it is not only healthier, but it functions particularly well in bone development. The perception among the Bedouin of the Sinai Peninsula is that drinking camel milk can alleviate any internal disorder. Besides these, bioactive proteins facilitate the primary immune system towards invaded pathogenic entities. They accelerate the defense system and the development of numerous cell lines, help in regulating the status of iron in the body and also possesses natural antioxidant activity (10). Treatment of acute and chronic disorders of the gastrointestinal part of digestive system by using Shubat (product of fermented camel milk) and camel milk has also been revealed (11).

Camel milk is full of balanced nutritional constituents and also displays a wide variety of biological actions that influence growth and development of particular body organs, metabolic responses towards nutrients absorption, digestion and fight against diseases. These biological actions are chiefly due to the proteins and peptides in milk. Biologically active peptides are generated in the gastrointestinal tract by the digestive action on milk (12). The positive health effects of milk proteins can be presented as antioxidative, anti-microbial, antihypertensive or immuno-modulatory and anti-thrombotic (13).

A wide variety of foodstuffs are prepared by camel's milk viz. different sour milk, *khoa*, cheese, ghee and butter. Regardless of typical perception among Southern Asia that camel milk cannot be used to manufacture ghee and butter because of the minute size of fat globules, some regional and foreign employees have developed techniques to prepare butter and ghee efficiently. Most typical dairy products manufactured by using camel milk are *kurth* (cheese), lassi (sour milk) and *dahi* (yoghurt) in north eastern *Balochistan* community (14,15).

Camels distribution, breeds and socio economic importance

Population and distribution of camels

There are about 27.01 million camels in the whole world, out of which 15 million are reported in Africa and 4 million in Asia region. Of this approximated globally distributed camel population, 2 million are two-humped camels (*Camelus bactrianus*) and 17 million are one-humped *(Camelus dromedarius*). Out of African population of camels, 70% are found in Somalia and Sudan, while Ethiopia, Chad and Kenya contain 12% camels. Pakistan with one million heads possesses about 23% camel population of Asian countries and rates fourth in the world following Somalia (6.2 millions), Sudan (3.3 millions) and Mauritania (1.3 millions) (16). Balochistan province has the largest camel population with 379528 heads, followed by Sindh (278424), Punjab (198964) and Khyber Pakhtonkhwa (63952) (17).

Camel breeds

There are a total of 50 camel breeds in the world. Out of which 27 breeds are in East, West and North Africa, Pakistan and Arabic Countries (Manga, Somalie, Gabbra, Benodir, Berabiche, Nord, Azmiyah, Deshi, Dera Ismail Khan, Ait, Khebbach, Ajjer, Steppe, Mekrani, khiva, Arab, Soudani, Chami, Targui, Adrar, Tibesi, OuledSidi, Cheikh, Chumbi, Mowallad and Khawar). There are about 20 breeds in West and North Africa, India and Arab Cape viz. Riverine, Pellahi, Gandiol, Fleuve, Azaouak, Bekaneri, Urfilla, Reguibi, Sahel, Umaniyah, Rashaidi, Grain, *Guban, Maghreb, Indi*, *Donkali, Mudugh*, *Turkana* and *Arabi.* Three camel breeds including Bishari and Anafi are found in Sudan and West Africa (18).

Twenty camel breeds have been documented in Pakistan, out of which 7 breeds are found in *Balo-*

chistan viz. *Brahvi*, *Kachhi, Kharani, Lassi, Makrani, Pishin and Rodbari*; 4 breeds in Khyber Pakhtonkhwa viz. *Gaddi, Ghulmani, Khader* and *Maya*; 5 breeds in Punjab namely, *Bagri, Brela* or *Thalocha, Campbelpuri, Kala-Chitta* and *Marecha* and 4 breeds in Sindh Province including, *Dhatti, Kharai, Larri* or *Sindhi* and *Sakrai* (19).

Socio-economic importance of camels

Camel is the most proficient and important livestock species which can survive and reproduce under harsh, hot and arid environmental conditions (20). Many pastoral families in semi-arid and arid regions of the globe are depending on camels for their livelihood. Camels are utilized for milk, meat, wool, hair and hide production, serving as draft, pack, riding and sport (racing, dancing) animal (21, 22).

In Pakistan, generally camels are kept by the migratory pastoralists in subsistence production system except some farmers of the irrigated plains and a small number used it for transportation in the cities. The camel contribution to the agriculture economy of Pakistan is not well documented or assessed. In addition to the pack and draft animal, camel is an economical and good source of milk, meat and hides for the people residing in the far-flung desert areas. Their hides are being used for manufacturing of leather products. Milking of lactating camels is performed three times in a day, generating about six liters per day in the dry period and nine liters per day in the wet season. The lactation period is of 12 months but it will also produce milk for the second year even if it is not conceived. Camel milk is marketed in small amounts and is also given away or distributed to others who live nearby. The key significance of camel milk is its accessibility in dry periods and during periods of drought when milk from other animals is scarce. The dairy potential of camel appeared higher than that of cow reared under the same climatic and feeding conditions (23). The physical and chemical properties of camel milk hinge on the quality of fodder and daily water intake. The amount of vitamin C is high which is immensely important for human health in dry lands where availability of vegetable and fruits are insufficient (24). The milk yield ranges between 900 and 4000 liters in a lactation period (250-500 days) of a camel. The camel meat is largely consumed by the people of rural and remote areas of Pakistan, as most of the people of cities have not developed the taste for it. According to an estimate over 5000 tons of it is being annually produced in Pakistan. The trend of slaughtering camels on *Eid-ul-Azha* is increasing day by day. Camel is also used as a power for ploughing land, drawing water from wells, oil extraction, grinding of wheat, corn, gram and sugarcane crushing (25).

Nutritional value and physico-chemical properties of camel milk

In nutritional point of view, 14 cups (1 cup equivalent to 245 mL) of camel milk can meet the daily energy requirements (2,300 or 2,200 Kcal) of adult man or woman. Similarly, daily protein needed for a person can be met with 8 cups of camel milk. In case of minerals, such as calcium or phosphorus the minimum daily requirements are 800 mg which can easily be obtained by 2.5 and 4 cups of camel milk for calcium and phosphorus, respectively. Vitamin C requirement of a person i.e. 60 mg.day-1 can be met by 7 cups of camel milk. Same is case for meeting the requirements of essential amino acids (26).

The value for acidity of camel milk is similar to cow milk between pH 6.5 and 6.75. The maximum buffering capacity of skim camel milk is at pH 4.95, compared to about pH 5.65 for skim cow milk. This gives indication that the composition of constituents with buffering capacity is different between camel and cow milk. Titratable acidity is between an equivalent of 0.13-0.16% lactic acid in fresh milk, which is slightly lower than the mean value of 0.17% for cow milk and seems to depend on the breed (27).

Whereas cow milk possesses a pronounced heat stability maximum at pH 6.7 and a minimum at pH 6.9, when determined at 130°C, with stability decreasing at pH lower than 6.7 and increasing at pH higher than 6.9, camel milk does not show an increased stability at pH 6.7. Heat stability of camel milk is much lower than that of cow milk. Heat coagulation time for cow milk at 130°C is about 40 minutes at pH 6.7, whereas camel milk coagulates at this temperature and pH in 2 to 3 minutes (35). The freezing point of camel milk was found to be between -0.57°C and -0.61°C (27). It is lower than the freezing point of cow milk, which is between -0.51°C and -0.56°C. A higher salt or lactose concentration in the camel milk as compared to cow milk may have contributed to this result.

Values for specific gravity measured and (27) depended on the breed chosen and varied between 1.028 kg.L-1 and 1.033 kg.L-1. These values are similar to values for cow milk, which are between 1.026 kg.L-1 and 1.034 kg.L-1. Other authors reported lower viscosity and density for camel milk than that for cow milk (28). A mean value for viscosity of Egyptian camel milk was 2.2 mPa.s, which is higher than the mean value of 1.8 mPa.s for cow milk (29). These contradictory results may be explained by the differences in husbandry, mainly in water supply (29. also observed strong seasonal variations in milk viscosity, specific gravity and titratable acidity. Milk of heifers deprived from water for several days was reported to be more dilute, probably to protect the calf from dehydration during dry periods (30).

Compositional characteristics

Proteins

It is found that dromedary camel milk contains protein contents in range of 2.15 to 4.90%(31). Camel milk from same strain has similar protein content (whey proteins and caseins) and different for other genotypes (1). *Hamara* and *Wadha* milk has less protein content as compared to *Majaheim* milk. With the change in season, protein content of same strain varied. It is found low in August (2.48%) and high in December (2.9%). Camel milk protein is classified into two main groups.

Table 1. Composition of camel milk

Constituent	Percentage	Author
Protein	2.15 to 4.90	Konuspayeva *et al.*, 2009
	3.1	Haj et al., 2010
Fat	1.2 to 6.4	Haddadin *et al.*, 2008
	3.5	Haj et al., 2010
	4.3 to 1.1	Konuspayeva *et al.*, 2009
Lactose	2.40 to 5.80	Konuspayeva *et al.*, 2009
	4.4	Haj et al., 2010
Mineral	0.60 to 0.90	Konuspayeva *et al.*, 2009

3.1.2. Caseins

Casein is a major part of protein in camel milk. Milk of Dromedary camel has 1.63 to 2.76% casein protein that constitutes 52 to 87% of total milk protein (32). In whole casein portion, β-CN is 65% and αs1-CN is 21% (33) while in milk of bovine β-CN is 36% and αs1-CN is 38% (34). Human milk and camel milk are found same when compare with the amount of β-CN. Camel milk has more digestibility and less allergic reactions in infants as αs-CN slowly hydrolyze than β-CN (41). 3.47% k-casein is present in camel milk casein (33) while 13% is found in milk of bovine (34). Other researches revealed that k-CN hide or runaway its exposure when it is present in shorter concentration (35). Electrophoresis results showed that there are no bands for k-CN. By using SDS-PAGE method the molecular weight of β-CN and α-CN is predicted as 28.601 kDa and 35.00 kDa (36) respectively. The molecular mass of these components in bovine milk are found higher which are 24 kDa (β-CN) and 22-25 kDa (α-CN).

The chain of amino acids of camel milk casein is determined by (37). Amino acid residues found in four caseins sequence were: αs1-CN, 207; αs2-CN, 178; β-CN, 217; k-CN, 162. This study revealed that arrangement of casein in milk of Dromedary camel is similar to bovine milk and very minute difference are found in these two. The difference was very obvious in arrangement of αs1-CN, and resemblance was clearly found in secondary casein structure of camel milk when they were studied with bovine casein arrangement. The amino acid composition of Dromedary milk was found similar to that of bovine milk. Comparing the composition of Dromedary milk and bovine milk, only glycine and cystine were present in lesser amount in casein of Dromedary milk (38).

The size distribution of casein micelles is in the range of 15 nm to 500 nm with a maximum in volume frequency between 260 nm and 300 nm (38). The distribution is significantly broader than that of cow milk, where it is in the range of 15 nm to 300 nm, with a maximum between 100 nm and 140 nm. The number of large micelles is significantly higher, which is unfavorable for formation of a firm coagulum in milk processing. A negative correlation between mean micelle size and k-CN content of cow milk was reported (39). Small micelles of about 60 nm contained 12% k-CN where as large micelles of about 200 nm contained about 2% k-CN. It was assumed that camel milk was low in k-CN or devoid of this protein (36).

Whey Proteins

After the casein protein in camel milk, whey protein constitutes 20 to 25% that make it the second biggest fraction of protein. The milk of Dromedary camel has a whey protein in range of 0.63 and 0.80% (32, 40). Whey protein present in buffalo milk is very much different from camel milk whey protein; the reason is camel milk don't have β-lactoglobulin as also observed for human milk (41). Camel milk β-lactoglobulin is found in traces, while α-lactalbumin comprises the major camel milk portion. In the milk of bovines, α-lactalbumin constitute only 25%, while β-lactoglobulin made 50% of the total whey protein that make it the major whey protein of bovine milk (33, 42).

Camel milk α-lactalbumin was noticed to have a molecular mass of 14.6 kDa and to consist of 123 residues, which is alike to bovine, human and goat milk α-lactalbumin. SDS-PAGE technique results demonstrated that in human milk whey protein consists of α-lactalbumin and lactoferrin band, while on the other side camel milk consists of mostly α-lactalbumin and blood serum albumin (BSA). There is huge difference in amino acid sequence of α-lactalbumin of camel milk compared to goat and bovine milk (41)

Whey protein of camel milk consists of some other main components such as peptidoglycan recognition protein, immunoglobulins, lactoferrin and serum albumin (3, 80). Iron retention by lactoferrin of different milk sources occurs at lower pH (<3-4). In difference, camel milk lactoferrin is discovered to drop iron from its C-lobe at pH 6-7 and from its N-lobe at pH 3-4 (25).

White color of camel whey separated from milk after coagulation is observed, while color of bovine milk whey produced after coagulation in cheese manufacturing is greenish (43). The explained behavior of camel milk whey may be because of light scatting from enhanced level of minute particles of fat globules and caseins.

Some features of camel milk whey protein were discovered to be different than those of other animal's milk whey proteins. It has been described that protein content in camel milk greatly influences its stability towards heat. Due to shortage or lack of k-CN and β-lactoglobulin in camel milk, it is not stable at a high temperature of 140°C as in case of bovine milk. Camel milk stability towards heat is not improved even by the incorporation of formaldehyde or urea (44), though whey protein of camel milk has been revealed to be relatively more stable towards heat than whey protein of buffalo or bovine. At 80°C for 30 min, the denaturation of camel milk whey protein was seemed to be less (32-35%) than that discovered for whey protein of bovine milk (70-75%) (45). The majority of the globules (88%) found in the camel milk whey emulsion exhibit a diameter larger than 2 mm at pH 5. In difference, only 1.5% of droplets synthesized from whey of bovine milk exhibit a diameter greater than 3 mm and about 80% of droplets exhibit a diameter less than 2 mm. Camel milk whey produces lesser foam volume than whey of bovine milk. Due to high level of α-lactalbumin, an increase in aggregation of camel milk whey because of the effect of heat, was observed at pH lesser than 5. This response leads to the conclusion that whey protein of camel milk shows more sensitivity towards acidity than whey protein of bovine milk.

It was analyzed the antioxidant potential and enzymatic hydrolysis of camel milk α-lactalbumin. Compared to α-lactalbumin of bovine milk, greater level of digestibility with both chymotrypsin and trypsin enzyme was revealed by camel milk, but alike sensitivity to pepsin was revealed by both proteins. In addition to structural differences between both proteins, α-lactalbumin of camel milk posses more antioxidant potential than bovine α-lactalbumin because of the fact that camel milk α-lactalbumin contains larger amount of amino acid residues that exhibit antioxidant activity.

Fats

It is reported that dromedary camel milk fat level varies from 1.2 to 6.4%. A constructive association between protein and fat contents of camel milk was observed (46). It was also revealed that fat contents can be reduced from 4.3 to 1.1% in the milk of thirsty camels (31).

Milk fat of dromedary camels carries a lower level of carotene and lesser concentrations of short chain fatty acids as compared to milk of bovine. It is well explained that white color of camel milk is due to this lower level of carotene. On the other hand camel milk contains higher amounts of long chain fatty acids as compared to fat of bovine milk. Likewise, concentrations of unsaturated fatty acids (43%) especially essential fatty acids were found higher in camel milk (1), while the concentration of unsaturated fatty acids in human milk was found higher than camel and bovine milk. It has also been revealed that the percentage of saturated fatty acids in camel milk fat is 67.7 that is lower than bovine milk in which the percentage is 69.9 (31). It is reported that the cholesterol level of camel milk's fat (34.5 mg.100 g-1) is higher as compared to cholesterol level (25.63 mg.100 g-1) of bovine milk fat (31). It was examined and explained solidification temperature and melting point of camel milk fat. These two features were discovered to be elevated in camel milk (30.5 ± 2.2°C and 41.9 ± 0.9°C respectively) in comparison to bovine milk fat (22.8 ± 1.6°C and 32.6 ± 1.5°C respectively), perhaps because of the fact that higher concentration of long chain fatty acids and lower concentration of short chain fatty acids are present in camel milk as compared to bovine milk in addition to the dissimilarities in isomeric features of oleic acid. It is suggested that high churning temperature from 20°C to 25°C can generate butter from cream of camel milk. These values of temperature are found higher than suggested for butter manufacturing of bovine milk cream i.e. 8°C -12°C. Moreover, fat of camel milk has also been surfaced to be more viscous. Fat globules are tightly linked to the proteins in camel milk owing to which traditional methods (such as churning sour milk) for the extraction of fat appeared futile (47).

The lipid fraction in camel milk is characterized by a high proportion of long chain fatty acids, which accounts for 96.4% as compared to 85.3% in bovine milk. A higher proportion of short chain fatty acids would be conducive for consummation, since short chain fatty acids alleviate digestion of the triglycerides. The higher proportion of (43.1%) non saturated fatty acids as compared to 38.8% in cow milk fat is favorable for the body metabolism. Most prominent is palmitoleic acid with 10.4%compared to 3.6% in cow milk fat, whereas the proportion of the essential linoleic acid is slightly lower in camel milk fat, with 2.9% as compared to 3.2% in cow milk fat (39).

Lactose

The dromedary camel milk lactose contents ranges between 2.40 to 5.80% (31). The nature of vegetation eaten by the camels in desert areas could be a significant factor for extensive variation in lactose contents. Camels generally like to take halophilic plants like *Salosa, Acacia* and *Artiplex* to fulfill their physiological necessities of salts (30). Consequently, camel milk is often explained as salty, sweet and bitter. It has been revealed that lactose contents remained unchanged over a period of time under dehydrated or hydrated conditions. However, in some dromedary varieties of the world, lactose contents found to be slightly changed over a period of time (48, 49)

Mineral Contents

The total amount of minerals are generally presented as total ash and in case of dromedary camel milk this value ranges between 0.60 to 0.90% (31). Fluctuations in mineral level were proposed to be due to the differences in feeding, breed, water intake (46) and analytical procedures (40). The mean values for zinc, manganese, magnesium, iron, sodium, potassium and calcium in mineral contents of dromedary camel milk (100g-1) are 0.53, 0.05, 10.5, 0.29, 59, 156 and 114 mg respectively (1).

Owing to the feed taken up by camels such as *acacia* which generally contains high amount of salts, the camel milk is supposed to be an excellent source of chloride (32). The depletion in major milk constituents and elevation in the chloride level of milk obtained from dehydrated camels might be a secondary cause for salty mouth feel of camel milk. Minerals' contents (sodium, potassium, iron, copper and manganese) in camel milk are reported to be significantly higher than for bovine milk. It was demonstrated that iron involves a variety of biological processes, including synthesis of deoxyribonucleic acid and transportation of oxygen, as well as its storage (50). Manganese was reported to play a significant role in metabolism of cell, whereas functionality of a number of enzymes including those involved in the protection of cells from free radical damage, is carried out in the presence of this element. In addition to that, the concentrations of magnesium, phosphorus and calcium in camel milk were similar to that found in bovine milk (1)

Vitamins

Numerous vitamins such as D, E, A, C and vitamins of B group are found in dromedary camel milk (46). Rich amount of vitamin C is present in camel milk. It was revealed that camel milk contained three to five times more vitamin C as compared to bovine milk. Therefore, for the inhabitants of desert areas where fruits and vegetables are quite inaccessible, camel milk can be used efficiently as an alternate source of vitamin C. The mean value of vitamin C concentration present in camel milk is 34.16 mg.L-1. It was reported that camel milk contained higher concentration of niacin (B3) as compared to bovine milk (1)

The concentration of riboflavin (B2) and vitamin A in milk of dromedary camels was revealed to be lesser than that of bovine milk. However, camels from Jordan exhibited high levels of Vitamin B12, folic acid and pantothenic acid than bovine milk. This data is ambivalent to that obtained (1) from milk of *Najdi* camels. This contradiction might be because of the differences in analytical procedures and camel breeds. However, the amounts of pyridoxine (B6) and thiamin (B1) in milk produced by dromedary camels was similar to those for bovine milk (46), while the level of vitamin E in camel milk was found very near to that of bovine milk (35).

According to USDA (2009), milk (250 mL) of dromedary camel nourish a normal adult by means of 10.5% of ascorbic acid (C), 5.25% of vitamin A, 8.25% of riboflavin (B2), 15.5% of cobalamin and pyridoxine and thiamin of the Recommended Daily Intake (RDI). In comparison, bovine milk (250mL) nourish a normal adult by means of 9% of vitamin A, 3.5% of ascorbic acid (C), 11.5% of pyridoxine (B6), 36% of riboflavin (B2) and 43.5% of cobalamin (B12) and thiamin of the RDI.

Bioactive native proteins

Immunoglobulins

Immunoglobulins are also called as antibodies, which are present in human or animal blood serum or body fluids to build body's immunity in response to certain antigens, bacteria and virus. Immunoglobulins are high molecular weight polypeptide chains. Immunoglobulins are categorized into five classes: immunoglobulin A (IgA), immunoglobulin D (IgD), immunoglobulin E (IgE), immunoglobulin G (IgG) and immunoglobulin M (IgM). The concentration of immunoglobulins in milk fluctuates, depending on several factors such as species, health status of animal and stage of lactation. Level of immunoglobulin G in camel milk is 1.64 mg.mL-1 as compared to 0.70, 0.67, 0.55, 0.63 and 0.86 mg.mL-1 for goat, cow, sheep, buffalo and human milk respectively (51).

Lactoferrin

Lactoferrin is a glycoprotein, and is also known as lactotransferrin. It hails from a class of transferrins. A familiar characteristic of this protein family is its ability to bind two metal cations (preferably Fe 3+) to the binding sites that are structurally closely related. The majority of lactoferrin is needed for transportation or storage of iron. Lactoferrin was reported to act as iron scavenging in body secretions (52).

Comparative research on lactoferrin level in camel, buffalo, cow, goat, sheep, mare, donkey and human milk was carried out (51). Research showed that lactoferrin level significantly varied. The highest concentration was found in human milk (1.7 mg.mL-1), while lowest level was observed in donkey milk (0.07 mg.mL-1). Lactoferrin contents of camel milk (0.22 mg.mL-1) were significantly higher than goat, sheep, buffalo and cow milk (53).

High lactoferrin contents (5.1 mg.mL-1) were observed in colostral camel milk on second day after parturition in comparison to about 0.5 mg. mL-1 in bovine colostral milk. After one month of parturition, the lactoferrin content in camel milk dropped to 0.34 mg.mL-1, while for bovine milk, value was 0.06 mg.mL-1. In another research sample of camel milk obtained at the end of the lactation, lactoferrin contents were 0.22 mg.mL-1 (37). Changes in lactoferrin level in normal camel milk and colostral camel milk showed that the lactoferrin concentration was maximum at first day and then reduced with milking (53), which was just like the pattern discovered in bovine milk (54). The research revealed that highest level of lactoferrin (2.3 g.L-1) was noticed after 2 days of parturition.

Indigenous enzymes

Lysozyme

Lysozyme breaks β (1-4) glycosidic linkage between N-acetylmuramic acid and N-acetyl-D-glucosamine residues in peptidoglycan, the component of microbial cell walls. Immunological research (53) on camel milk lysozyme revealed that there is no antigenic resemblance between bovine and camel milk lysozyme, which indicates alike structures. The level of lysozyme in milk differs extensively from 79 mg.100 mL-1 in mare milk (55) to 13 μg.100 mL-1 in buffalo milk (2). According to different researches, camel milk contains 228 and 500 μg.100 mL-1 of lysozyme (56, 2) compared to 13 (54) and 37 μg.100 mL-1 in cow milk (53). The variations in the observed values were mainly due to the effect of lactation period.

A comparative analysis (51) of lysozyme level in milk of different species reported that camel milk had significantly higher level of lysozyme than buffalo, cow, goat and sheep milk. However, concentration of lysozyme in camel milk was less than those in donkey, mare and human milk. The equivalent level of lysozyme in camel milk was 18, 11, 8 and 10 times that of buffalo, cow, goat and sheep milk, respectively.

Lactoperoxidase

Lactoperoxidase is present in tears, saliva and milk. It exerts bactericidal activity generally on Gram negative bacteria thus contributing to non-immune host defense system. It is thought that the major function of lysozyme in milk is the protection of the udder against infections wreaked by microbes (57). Lactoperoxidase is quite resistant to acidic and proteolytic digestion.

Lactoperoxidase present in camel milk is a monomeric protein, which shows about 79.2% sequence likeness to human eosinophil peroxidase and 79.3% sequence likeness to human myeloperoxidase. Both eosinophil peroxidases and myeloperoxidase are dimeric proteins (37). Lactoperoxidase was extracted and purified from bovine and camel milk and their molecular weights were approximated at 88 and 78 kDa respectively (58).

Heat stability of protective proteins

A research has been carried out to check the effect of heat treatment on protective proteins as lactoferrin, lysozyme and immunoglobulins (IgG) (51). In this research, buffalo, cow and camel skimmed milk samples were subjected to heat treatment at 65, 75, 85 and 100°C for half an hour. The results revealed that heating of the three types of milk at 65°C for half an hour had no considerable effect on lactoferrins and lysozymes. However, a considerable decrease in immunoglobulins action was observed. The entire activity of immunoglobulin in both buffalo and cow milk vanished at 75°C for half an hour as compared to 68.7 % reduction in the activity of camel milk immunoglubulin. The whole activity of lactoferrins vanished at 85°C for half an hour in these three types of milk. However, at this temperature, the loss in activity of lysozyme was 81.7, 74 and 56% for buffalo, cow and camel milk, respectively. Generally, it was proposed that camel milk protective proteins are more heat-stable than buffalo and cow milk proteins.

Antimicrobial action of camel milk native proteins

Camel milk also carries antimicrobial activity and it is effective against Gram negative and Gram positive bacteria (59). The antimicrobial activity of camel milk against these microorganisms is due to the presence of antimicrobial agents such as immunoglobulins, hydrogen peroxide, lactoferrin, lysozyme and lactoperoxidase. Camel milk lactoferrin inhibits the growth of Salmonella typhimurium by holding iron and making it unavailable for its growth (2).Camel milk has the ability to inhibit the growth of pathogenic microorganisms because it contains number of enzymes with anti-bacterial and anti-viral properties. It can be assumed that lactoferrin in colostral milk acts as an iron scavenger, which depletes the milk from free iron, and thereby, slows down microbial growth. Iron-saturated lactoferrin, which is found in milk from the second week to the end of the lactation period, may primarily prevent microbial growth in the gut. This would help the new-born, which is easily infected, to survive the first weeks, until its own immune system becomes developed, and the gut becomes adapted to food digestion. Iron-saturated lactoferrin could also be a source of iron for the suckling, once the protein is degraded in the gut. Lactoferrin prevents microbial growth while lactoperoxidase suppress gram negative bacteria and most effective in raw milk during the first four days. Peptidoglycan recognition protein which widens the anti-microbial activity and stimulates the immune system. Lysozyme inhibits the growth of bacteria and has effective influence on the storage of camel milk. Immunoglobulins possess several traits which give them tremendous advantage over conventional antibodies (45).

The inhibitory action of camel milk lysozyme as compared to bovine milk lysozyme and egg white lysozyme was analyzed against several strains of bacteria (53). Results exposed that camel milk lysozyme had a higher lysis value towards Salmonella typhimurium in contrast to other lysozymes. Lactococcuslactis subsp. Cremoris was extremely affected by bovine milk lysozyme but that strain was not affected by camel milk lysozyme. Escherichia coli and Staphylococcus aureus were not affected by any lysozyme.

It has been discovered that lysozyme improves the anti-bacterial action of lactoferrin. Commercial preparations of lysozyme are an exciting substitute to nitrate as an anti-sporulating agent, inhibiting the growth of Clostridium tyrobutiricum in dairy products (60).

The inhibitory activity of camel and bovine milk lactoferrins against some strains of bacteria was studied (53). Both kinds of lactoferrins were found very effective towards Salmonella typhimurium.

Camel milk lactoperoxidase was purified and its inhibitory effect against lactic acid bacteria and some strains of pathogenic bacteria was analyzed (2). Camel milk lactoperoxidase had a bacteriostatic action against Lactococcuslactis and Staphylococcus aureus. The destructive effect of camel milk lactoperoxidase on the cell walls of these microbes was observed.

Processing of camel milk

The vast amount of camel milk is consumed as a fresh or as a naturally fermented product. *"Susa"* a product consumed in North-Eastern Africa, it is made by incubation of milk in smoke sanitized wooden buckets for about one to three days. The consistency of fermented camel milk is thin. A flocculent precipitate is formed rather than a firm coagulum. Studies carried out in Kenya showed that the quality of "Susa" can be improved using selected mesophilic starter cultures rather than spontaneous bacterial contamination for fermentation. The Somali consumers preferred this novel product to the traditional product. Growth of bacterial strains used for cow milk fermentation may be inhibited by the natural antimicrobial activity of camel milk (2). Stronger initial growth was reported for Lactobacillus acidophilus. This could be due to a higher content of non-protein nitrogen in camel milk (27).

Butter is traditionally produced by skimming creamed up fat and by subsequent churning. This technique cannot be applied to camel milk fat, since the milk shows little tendency to cream up. Butter was produced by heating the milk at 65°C for 30 minutes and separating the cream by centrifugation. To obtain a reasonable butter yield, camel cream was churned at temperature between 22°C and 25°C. The corresponding temperature for cow milk cream is between 8°C to 14°C. The reason for this difference is the high melting point of camel milk fat, which is at 40°C to 41°C. This seems to shift the ideal ratio of solid to liquid fat at a given temperature towards a point higher than that of cow milk fat (38). It was shown that creaming of camel milk fat was markedly improved by dissolution in skim cow milk. Cow milk fat dissolved in skim camel milk, on the other hand showed a sharp reduction in the ability to cream up. It can, therefore, be concluded, that agglutinin (immunoglobulin M), the factor which promotes creaming of cow milk fat, is low or devoid of camel milk (38). Churning of camel milk fat may be aggravated by the much lower ratio of lipid droplet to milk fat globule membrane (MFGM) in camel milk fat globules. The average moisture content of camel butter is 12.65%, and thus much lower than the content in cow milk butter, which is 15-56% (61). This may explain the sticky texture of camel milk butter. Camel milk butter may be more susceptible to light oxidation due to the higher amount of non-saturated triglycerides. It would be well worthy to study the sensitivity of camel milk fat towards lipolysis and oxidation, bearing in mind that isolation in camel keeping countries is high and the total surface of milk fat is larger, since the volume to surface ratio of camel milk fat globules is only 4-40 μm (40) as compared to a value of 5.32 μm for cow milk fat globules. Light oxidation of fresh camel milk may be a concern, since milk is often stored in transparent containers.

Similarly to horse milk, the renneting capability of camel milk is poor (27). Addition of 2% $CaCl_2$ increased curd firmness slightly, whereas addition of higher percent amounts decreased coagulation time without further improvement of curd firmness. Renneting is probably low, because the mean size of casein micelles is about double of cow milk casein micelles. Electron micrographs showed that the network formed at the coagulation point was less compact than in renneted cow milk and the micelles were linked merely by contact adhesion with little change in the original micelle structure, whereas the network formed in cow milk consisted of fused micelles (62). Cheese yield is in the range of 35% of milk dry mass compared to about 85% for cow milk. This result may be explained by the lower amount of total solids, the poor rennetability, the smaller fat globules, the sodium concentration, which is often higher than in cow milk, and the higher proportion of whey proteins. Higher cheese yield was obtained with sophisticated technology, addition of CaCl2 and fourfold higher chymosin concentrations than used in cow milk. Higher cheese yields were also obtained when the milk was blended with milk from ruminants (63). Most studies on cheese production from camel milk report the production of a low fat cheese with slightly bitter taste (36). It can be assumed that this type of cheese finds little consumer acceptability in camel keeping countries, where cheese has to be introduced as a novel product.

Different studies showed that seasonal variations in camel milk production are great and much of surplus milk is collected during the rainy season. Processing camel milk into pasteurized and fermented products will therefore be of great advantage, allowing the camel small-holder to commercialize his milk (36). Camel milk is commercially pasteurized in Saudi-Arabia and Mauritania. Problems may arise from the low heat coagulation time of camel milk and a tendency to flocculate. There are also environmental and socio-economical factors which make milk processing by pasteurization a difficult task in arid countries (64).

A problem, which arises from the higher general heat stability of camel whey proteins, is that the most commonly used methods for determination of pasteurization all fail. The inactivation of phosphatase and lactoperoxidase do not occur to the same extent. Positive reaction of the former by short time heat denaturation is able to detect 0.1% raw milk in pasteurized cow milk. The latter is able to detect 5% raw milk in high temperature treated cow milk. Both reactions do not work in camel milk, even not when modified in a way similar to the pasteurization proof of goats milk by alkaline phosphatase (65).

Fermented products of camel milk

Fermented products of camel's milk vary according to the method of processing. *Shubat* is camel's sour milk from Kazakhstan (66). *Lehban* is fermented products from camel's milk in Syria and Egypt (45). Kefir is the Caucasian fermented camel's milk. *Tarag* is cultured milk product which is just like yogurt in Mongolia, while *Unda* is an item prepared by alcoholic and lactic fermentation of camel's and other ruminants milk (30). *Ngurunit* community is producing cultured camel's milk by straining the milk to remove dirt particles, boiling, cooling to ambient temperature and eventually culturing the fresh milk (67). *Gariss* is product manufactured using camel's milk in Sudan and is a fermented camel's milk that is not available all the time for a family, because camels are often carried far away in the search of pastures (9).

Medicinal perspectives

Anti-schistosomal

Schistosomiasis is one of the most endemic parasitic attacks of human after malaria. The infectious species effecting human are Schistosoma japonicum, Schistosoma haematobium and Schistosoma mansoni. A severe hepatosplenic disorder is developed by 5 to 15% of patients bitten by Schistosoma mansoni and the problem can be more fatal if not treated in time. Although infections can be treated by schistosomicides, but chemotherapy treatment is not suitable for the long-term management of these kinds of infections and the main objective of World Health Organization is vaccine development for the treatment of schistosomiasis (68). Research was performed to examine the anti-schistosomal action of mature and colostral camel milk on mice which was infected by Schistosoma mansoni. An immunomodualatory activity of mature and colostral camel milk in infected mice was observed by the induction of GST (Glutathione-s-transferase) and IgG (immunoglobulin G) before and after the infection.Therefore, feeding the patient with colostral and mature camel milk stimulate a particular immune response that defends against Schistosoma mansoni. The immuno-protective phenomenon results in an improved level of GST that detoxifies the body more efficiently. Hence it was announced that mature and colostral camel milk exhibits a protective effect against schistosomiasis infection.

Liver is among the biggest parts of the human body and the primary site for extreme metabolism and detoxification as well as excretion. In human body, metabolism for the provision of energy and detoxification of various components is carried out in liver. So it has an amazing function in the performance, maintenance and managing homeostasis of our bodies. It is engaged with almost all the biochemical routes to development, battle against infections and diseases, essential nutrients provision, energy supply and reproduction. As liver is involved in a variety of functions, so it is always at risk to be effected by the drugs as well as toxic substances that are absorbed from intestine. In addition to toxic substances and drug injuries, microbial and viral infection may also lead to severe liver damage (69). Acute as well as chronic liver disorders constitute health and medicinal concerns throughout the world and are difficult to treat with available resources in an efficient way (70). Liver illnesses are among the critical diseases on the whole planet today. They create a severe problem to worldwide public health. To date current medications have a slight to offer for relief of hepatic illnesses and it is generally the plant based measures which are employed for the therapy of liver diseases (71). For that reason, management of liver disorders through complementary and alternative medicinal treatments is of substantial interest. Liver malfunction is scientifically a related issue, which records a considerable population of all the reported cases of serious liver failing (72). Therefore, hepatoprotective medications are suggested frequently for the eradication of liver disorders. The chances of toxicity may be reduced by developing therapeutical agents from natural products that can be effectively used for the manipulation of disease.

Non-A, non-B hepatitis is brought on by hepatitis C virus (HCV) globally, which is the major etiologic agent and transmitted parenterally (73). Inability of the diseased individuals to eliminate virus results in continual infection in about 80% of reported cases. Progressive liver diseases like cirrhosis, hepatic failure and hepatocellular carcinoma are developed by the patients who are chronically infected. The world's highest HCV prevalence rates are reported in Egypt (74). Apart from the presently used medical therapies (IFNα-2a, -2b, pegylated, ribavirin), Egyptian patients are being treated by several traditional medicines. Among those, camel milk is used most widely and considerable improvement in general fatigue has been observed in about 50% of the patients (75).

Paracetamol induced hepatotoxicity

Paracetamol or acetaminophen is commonly used as medication, antipyretic drug and is well recognised to cause hepatotoxicity at its over dose (76). Excess of paracetamol (PCM) causes saturation of conjugated pathways that result in glutathione reduction and accelerating the development of harmful reactive metabolites. Elevated level of reactive metabolites amplifies the level of hepatotoxicity with high formation rate of protein adducts, oxidative stress and mitochondrial malfunction. Evaluation of liver toxicity is carried out by calculating the marker enzymes, such as glutamic oxaloacetic transaminase (GOT) and serum glutamic pyruvic transaminase (GPT) which are initially present in high amounts in the cytoplasm. When there is hepatic damage these enzymes flow into blood stream in accordance with rise of hepatotoxicity. Increased values for serum enzymes are signs of loss of functional integrity of cell membrane in liver and cellular leakage (77). But the elevated level reduced to normal value after seven days treatment of camel milk. This indicates that camel milk offers protection by maintaining the structural integrity of hepatocellular membrane against paracetamol induced toxicity.

Treating male mice with paracetamol led to accelerate the activities of serum enzymes GOT, GPT and alkaline phosphatase (ALP) levels in comparison to normal mice, while mice managed with camel's milk showed marked reduction in increased level of serum GPT, GOT and ALP enzymes induced by paracetamol. Increased level of triglycerides and cholesterol was also observed in paracetamol treated mice, while these values were significantly reduced in mice treated with camel milk. Protein and albumin level was also reduced in mice treated with paracetamol, while increase in protein and albumin level and a marked decrease in globulin level was recorded in mice treated with camel milk as compared to normal mice. Results indicated that paracetamol is capable of causing considerable modifications in biochemical parameters and affecting the functionality of enzymes which possess antioxidant activity. Camel milk administration after paracetamol exposure, reduced paracetamol associated hazards. Therefore, using camel milk could be very effective for the treatment of paracetamol toxicity (78).

Camel milk and allied health claim

Camel milk has an adjuvant effect to insulin therapy in control of diabetes. Raw camel milk against type I diabetes has shown encouraging results and average daily insulin requirements showed a decrease of about 30-40% in 92% of patients. Camel milk is rich source of insulin or insulin like protein that is not destroyed while passing through the stomach (79).

Studies have reported that camel milk is suitable to children suffering from food allergies. The role of camel milk against food allergies can be attributed to the fact that it does not hold any allergens that are much effective in cow milk. It does not contain β-lactoglobulin (80), but β-casein is there. Another important fact is the presence of immunglobulins in camel milk similar to that of mother's milk, which lessen the allergic reactions in children as well as build up their upcoming response to the foods (81).

Hypocholstrolaemic effect has been observed when Gariss (fermented camel milk), containing Bifidobacterium lactis (BB-12) is administered to rats (in vivo) (82). The mechanism is still uncertain, but some studies indicated that hypocholestrolaemic action is due to relation among bioactive peptides obtained from cholesterol and camel milk proteins that lower the cholesterol level (83). While others proposed that orotic acid present in camel milk is considered to be responsible for reducing cholesterol level in rats (84) and human subjects (85).

Apoptosis is a physiological cellular process of cell death that is started by a wide range of external and internal signals and stimulating elements and hence, dangerous in various disease processes. These signals or stimuli instruct the cells to undergo apoptosis by the activation of several proteins known as caspases. The internal signals can start apoptosis through mitochondrial oxidative stress brought on by free radicals.

Table 2. Overview of Diseases Prevention by Camel Milk

Diseases	Author	Model
Diabetes	Agarwal *et al*., 2005 Agrawal *et al*., 2007 Mohammad et al., 2009	Human
Hypocholstrolaemic	Elayan*et al*., 2008	Rat
Cancer	Kontou*et al*., 2011	Human
	Magjeed, 2005	Human
Breast cancer	Hesham *et al*., 2012	Human
Schistosomiasis	Amany*et al*., 2005	Rat
Liver disorder	Yamazaki *et al*., 2005	Human
Hepatitis C (HCV)	Genovese *et al*., 2005 Redwan *et al*., 2003	Human
Autism spectrum disorder	Adams, 2013	Human

This involves a balance between anti-apoptotic and pro-apoptotic proteins, which increase permeability of outer membrane of mitochondria for the discharge of caspase activators (86). Chemoprevention by nutritional supplements in the form of functional foods has a deep-rooted beneficial part in health improvement and appeared as a novel strategy to control cancer (87). The study examined the effect and the actual mechanism of camel milk on the growth of human cancer cells by using an in vitro model of human breast, Michigan Cancer Foundation-7 (MCF7) cancer cells and human hepatoma (HepG2) cancer cells. Outcomes revealed that camel milk considerably restricted MCF7 and HepG2 cells growth through the activation of caspase-3 mRNA and activity levels, as well as the introduction death receptors in both cell lines. Camel milk restricted MCF7 and HepG2 cells survival and growth through the activation of both the external and internal apoptotic routs. These findings are of potential clinical importance to humans in that it reveals the molecular mechanisms involved and could describe the historical proof for the successful use of camel milk in the treatment of various health issues (88).

To explore the macromolecules in camel's milk that may be responsible for its protective potential, two camel milk proteins: lactoferrin and amylase have been screened and analyzed for their potential anti-HCV activity. Lactoferrin showed significant activity against

HCV cell entry into both human naive leukocytes and HepG2 cells, while amylase failed to exert any antiviral activity in the same tissue culture system (89).

Conclusion

Animal resources, such as camel's milk and its various products, have comprehensively been dealt with regarding their nutritive and therapeutic effects. Despite the large camel population in Pakistan, camel milk is not utilized to any significant extent probably due to unawareness of the use, and the market value of camel milk or because of its saltish taste and high acidic nature. However, it is much more nutritious than that from cow milk because it is low in fat contents and higher in potassium, iron and vitamin C. It is an excellent source of well-balanced nutrients and also exhibits a range of biological activities that influence digestion, metabolic responses to absorbed nutrients, growth and development of organs and resistance to diseases.

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