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Apeksha G Sonara
M.Tech. Scholar, Department
of Dairy Chemistry, SMC
College of Dairy Science,
Anand Agricultural
University, Anand, Gujarat,
India

Nilesh Vadhiya
M.Tech. Scholar, Department
of Dairy Chemistry, SMC
College of Dairy Science,
Anand Agricultural
University, Anand, Gujarat,
India

Somnath Sahu
M.Tech. Scholar, Department
of Dairy Chemistry, SMC
College of Dairy Science,
Anand Agricultural
University, Anand, Gujarat,
India

Pravin D Chaudhary
M.Tech. Scholar, Department
of Dairy Chemistry, SMC
College of Dairy Science,
Anand Agricultural
University, Anand, Gujarat,
India

BM Mehta
Professor, Department of
Dairy Chemistry, College of
Dairy Science, Kamdhenu
University, Amreli, Gujarat,
India

Corresponding Author:
Apeksha G Sonara
M.Tech. Scholar, Department
of Dairy Chemistry, SMC
College of Dairy Science,
Anand Agricultural
University, Anand, Gujarat,
India

Chemistry of camel milk proteins: Chemistry, processing effect, techno-functional & nutritional properties

Apeksha G Sonara, Nilesh Vadhiya, Somnath Sahu, Pravin D Chaudhary and BM Mehta

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Abstract

Camel is considered as a goal animal of the 21st century because it produces high quality milk under extreme temperature, deficiency of pasture and dearth of water. It is commonly consumed globally because of its salty taste, high vitamin C concentration and its medicinal properties mostly. Camel milk and its product; meat and urine considered to be superfood due to their therapeutical value and useful against different diseases such as diabetes, jaundice, anemia, malaria, dropsy, flatulence, tuberculosis, HIV, cirrhosis of the liver, cancer, rickets, arthritis besides it can detoxify snake venom. Camel milk is being used as an alternative to bovine milk for infants and young children in developing countries due to its unique composition, functional and therapeutic properties and similarities with human milk. Camel milk contains many protective proteins that have therapeutic properties like anti-cancer, anti-diabetic, ACE inhibitory, antioxidative, antibacterial properties and less allergenic due to absence of β -lactoglobulin. Different Processes such as pasteurization, homogenization, sterilization, and non-thermal processing all affects the protein structure and functionality. Due to variation in composition of camel milk especially in protein faces difficulties during processing and product manufacturing. The average casein and whey protein content in camel milk varies between 2.3 to 1.9% and 0.7 to 1.0% respectively. Camel milk protein contain higher amount of hydrolysed protein (β -casein) and lack of β -lacto-globulin. Camel milk is also being extensively studied for its techno-functional properties like foaming, gelling and emulsification. Camel milk has better foaming and emulsification properties and less gelling properties than bovine milk.

Keywords: Camel, vitamin C, β -lactoglobulin, whey acidic protein

Introduction

Camels contribute big role in lives of many people particularly which stay in arid or desert area and semi-arid areas of the world and also significant contributors in their ecologies. Camels live in the vast pastoral areas in Africa and Asia and are divided into two different species belonging to the genus *Camelus*. Dromedary camels (*Camelus dromedarius*, one humped) that mainly live in the desert areas (arid), and Bactrian camel (*Camelus bactrianus*, two-humped) which prefer living in the cooler areas. It is a bulky animal that stay in desert with a population of nearly 34 million in that 89% are *Camelus dromedaries* species and 11% are of *Camelus bactrianus* (FAOSTAT, 2019) [17]. It contributes 0.36% share of the world's milk production in which Asian countries reported 8% share. In India, camels are mainly highest reported in state of Rajasthan (81.4%) and other states Gujarat (7.6%), Haryana (4.7%), Bihar (2.2%), and Uttar Pradesh (2.0%).

Camel Milk Composition

Camel milk composition has been studied in different parts of the world. The camel milk contains average 3.4% protein, 3.5% fat, 4.4% lactose and 0.79% Ash (Al Kanhal and Hamad) as shown in table 2. It is a noble source of nutrients like protein and vitamin C (3-5 times more compare to bovine milk) in addition to comprising much more therapeutic value when compared to the milk of any other animal species. Camel milk composition varies with breed, geographically, feeding condition (Konuspayeva *et al.*, 2009) [35].

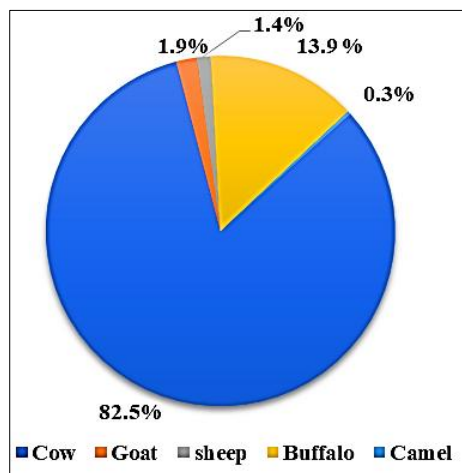


Fig 1: Percentage of the total quantity of milk produced by different species in the world

Table 1: Chemical compositions (%) of milk of different camel species

Species	Composition (%)			
	Fat	Protein	Dry Matter	Lactose
Bactrian	6.67	3.33	13.07	2.77
Dromedary	5.94	3.03	12.39	3.12
Hybrid Camel	6.09	3.28	11.91	3.04

(Konuspayeva, 2007) ^[35]

Table 2: Composition of camel milk comparison with other species

Species	Chemical composition (%)				
	Moisture	Fat	Lactose	Protein	Ash
Camel	86-88	2.9-5.4	3.3-5.8	3.0-3.9	0.6-1.0
Cow	86-88	3.7-4.4	4.8-4.9	3.2-3.8	0.7-0.8
Buffalo	84-85	6.0-9.8	4.5-5.0	3.4-4.0	0.7-0.8
Goat	87-88	4.0-4.5	3.6-4.2	2.9-3.7	0.8-0.9
Sheep	79-82	6.9-8.6	4.3-4.7	5.6-6.7	0.9-1.0
Human	86-87	3-5	6.9-7.2	0.8-0.9	0.15-0.2

(Kanhil and Hamad, 2010)

Camel milk protein

Milk proteins are important bioactive components which provide essential amino acids and are also an energy source. Different technological processing applied in milk sterilization, pasteurization, cheese making are to a large extent determined by the properties of the milk proteins. The milk obtained from camel discrete from bovine milk in composition and structure of its protein components, which influences its functional and biological properties. Camel milk have high nutritional value due their unique components and some are homologous to human milk; thus it can be a good replacement for human milk in cases in which the source of human milk substitute and also good application in infant formula. Camel milk contains high amount of Ig, protective enzymes and insulin like proteins. The unique protein found in camel milk such as peptidoglycan recognition protein, whey acidic protein and lactophorin more in camel milk. In that camel milk proteins has satisfactory balance of essential amino acids which is important aspects of human diet, containing a high amount of β -casein (65% of total casein) and less κ -casein and a lack of β -lactoglobulin (El-Agamy, 2009; Hinz *et al.*, 2012; Kappeler *et al.*, 2003) ^[14, 26, 33].

Amino acid profile of camel milk protein

The major amino acid in camel milk is glutamic acid. It has high content proline, leucine, valine and isoleucine which is important cell growth act as branch chained amino acid. The essential: non-essential AA ratio in camel milk, cow milk and human milk are 0.93, 1.0 and 1.07 respectively which is important in human for protein utilization (Zaho *et al.*, 2015) ^[58]. In camel milk higher amount of sulphur containing amino acid present like methionine, cysteine which are important for working of central nervous system. The ratio of cysteine: methionine is lower in camel milk (0.38) than in cow (0.5) and human (0.6) milk due to the high content of methionine in camel milk proteins.

Table 3: Essential amino acid profile (g/100 g protein) of camel milk in comparison with cow & human milk

Essential AA	Camel	Cow	Human
Arginine	4.03	3.65	3.3
Histidine	2.7	3.25	2.8
Isoleucine	5.10	4.9	3.7
Leucine	9.7	9.3	9.5
Lysine	7.2	8.10	10.1
Methionine	3.15	2.45	1.7
Phenylalanine	5.0	4.20	3.9
Threonine	5.73	7.25	8.3
Tryptophan	1.20	1.40	0.5
Valine	6.65	7.60	8.2

Haenlein *et al.*, 2017 ^[60]

Table 4: Non-essential amino acid profile (g/100 g protein) of camel milk in comparison with cow & human milk

Non-Essential AA	Camel milk (g/100 g Protein)	Cow milk (g/100 g Protein)	Human milk (g/100 g Protein)
Alanine	3.0	3.95	4.2
Aspartic	6.98	7.0	6.7
Cysteine	1.20	0.9	1.1
Cystine	1.50	2.45	2.1
Glutamic	21.70	18.60	16.8
Proline	12.00	9.85	10.6
Serine	5.20	6.15	4.1
Tyrosine	4.55	4.6	2.9

Haenlein *et al.*, 2017 ^[60]

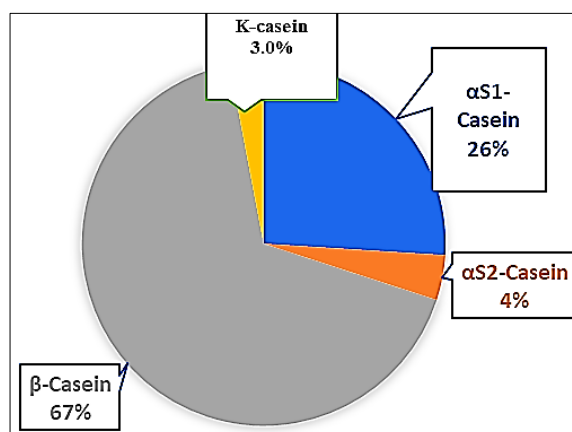
Table 5: Concentration of Different proteins in camel milk

Protein	Concentration (g/L)
α_{S1} -Casein	5.6
α_{S2} -Casein	0.9
β -Casein	15
κ -Casein	0.7
α -Lactalbumin	1.7
Serum albumin	0.46
Immunoglobulin G	0.8-13
Whey acidic protein	0.16
Lactoferrin (mg/L)	20-2100
Lysozyme (mg/L)	0.6-45
Lactoperoxidase (mg/L)	10
PGRP (mg/L)	15
Insulin (mIU/L)	33-55
Compiled from: Kappeler, 1998; Konuspayeva <i>et al.</i> , 2007; Omar <i>et al.</i> , 2018; Mohamed <i>et al.</i> , 2020 ^[32, 35, 61, 41]	

Casein from camel milk

The total protein content of camel milk varies from 2.0 to 3.2%, and is composed of two main fraction are caseins and whey protein. Casein is a phosphoprotein which precipitates in raw milk during acidification to pH 4.6 at 20 °C. Major fraction of Camel milk protein is casein which is about 2.4%

of total protein (76% -78% total nitrogen). Camel casein micelles are around 380 nm in size, nearly double to that of bovine milk casein micelles which observed 150 nm (Berhe *et al.*, 2017; ElAgamy, 2006)^[6, 14]. Due to larger diameter leads to poorer aggregation (omar *et al.*).

**Fig 2:** Percentage of the different casein content of camel milk

Casein of Camel milk are more homologous with that of human milk. It contains about five times more hydrolyzed protein β -casein as compared to cow's milk and it is major casein fraction same as human milk. It contain less amount of glycosylate κ -casein (3.5%) compare to bovine milk (13%). Higher amount of proline amino acid residues content in camel caseins may lead to destabilization of secondary structures in a more pronounced manner than it

does in cow milk caseins (Kappeler, 1998)^[32]. The concentration of caseins in camel milk are shown in Table 5. α_{S1} - and β -CN of camel milk are phosphorylated to about the same extent as in cow milk, while α_{S2} -CN is more heavily phosphorylated (Most hydrophilic) than that of cow milk casein. Molecular properties of camel milk casein shown table 6.

Table 6: Molecular properties casein fraction from camel milk

Properties	α_{S1} casein	α_{S2} casein	β -casein	κ -casein
Molecular weight	24.7	22	24.9	22.3
Amino acids	215	176	217	162
Isoelectric point	4.41	4.58	4.66	4.10
Concentration (g/l)	5.6	0.9	15	0.7
Phosphorylation	5	9	4	1

Hailu *et al.*, 2016^[25]

Whey protein from camel milk

Whey protein is another major fraction of camel milk which reported 0.6-0.8% of total camel milk protein (26-28% of total nitrogen). Camel milk contain unique composition of whey protein components (ElAgamy, 2006; Hinz *et al.*, 2012)^[15, 26]. It found to be have more unique protein; WAP, PGRP which are absence in bovine as well as human milk.

β -lactoglobulin is the major protein allergen which is absent in camel milk (Maqsood *et al.*). Due to absence of allergenic whey protein leads to more similarity and quite closer with human milk and helpful for prevention of cow milk allergy. Major whey protein present in camel is α -lactalbumin which contains 123 amino acid residues same as bovine α -La and MW 14.6 kDa. It contains more amount of

antioxidant rich amino acids residues. Camel milk contains the highest level of IgG (1.64 mg/ml) in that two variant IgG2 and IgG3 which provide additional functionality (Abbs *et al.*, 2013) [1]. Serum albumin in camel milk is higher compare to bovine milk (2.2 g/l). Serum albumin is

less susceptible to heat than Serum albumin from bovine or buffalo milk, and it has been demonstrated that denaturing camel Serum albumin at 100 °C for 20 min is equal to heating bovine and buffalo SA at 85 °C for 20 min (El-Agamy, 2000) [13].

Table 7: Comparison of whey protein fractions in selected milk species

Whey protein fraction	Camel (g/L)	Bovine (g/L)	Human (g/L)
β-lactoglobulin	-	3.1	-
α-lactalbumin	2.3	1.1	3.2
Serum albumin	2.2	0.35	0.57
Immunoglobulins	1.5	0.8	1.4
GlyCAM-1	0.95	0.30	
Whey acidic protein	0.16	-	-
Peptidoglycan recognition protein	0.11	-	-
Lysozyme	0.00015	0.00007	0.13
Lactoperoxidase	0.0011	0.03	0.00078
Lactoferrin	0.19	0.1	2.3
Hailu <i>et al.</i> , 2016 [25]			

Protective protein

In camel milk specific proteins that is antibodies or immunoglobulins and non-specific proteins which include lysozyme, Lactoferrin, PGRP and lactoperoxidase.

PGRP (Peptidoglycan recognition protein)

The peptidoglycan recognition protein is an antibiotic protein that is secreted from white blood cell. It has the ability to depolarize bacterial membranes. Inactivation of pathogens occurs by binding to peptidoglycan structures in bacterial cell walls act as pathogen inhibitor for both gram positive and gram negative bacteria; thus the name was given peptidoglycan recognition protein (PGRP). Intracellular component of neutrophils, has been isolated from camel milk. Camel PGRP protein is rich in arginine, but poor in lysine, although the pI (7.94) is highly basic. It presents in camel milk at concentration 110-120 mg/l (Mohamed *et al.*, 2020) [41]. It contain 172 amino acid and 19.1 kDa MW. PGRP concentration reduced during lactation (19%) and increased in the event of severe mastitis by 45% (Kappeler *et al.*, 2004) [30].

Lysozyme

Camel and Bovine milk both contains trace levels of lysozyme tested, and both have been reported to have a similar molecular weight (MW) of 144 KDa (El-Agamy *et al.* 2000; Poltronieri *et al.*, 2012) [13, 48]. However, the enzyme is not expressed in a healthy lactating mammary gland, and it was not discovered in milk that had no mastitis (Kappeler *et al.*, 2004) [33]. The traces that have been found in camel milk likely came from the blood serum.

Lactophorin

Lactophorin is glycoprotein that reacted to the antisoluble glycoprotein of milk fat globule membrane was purified from the proteose-peptone of whey. It consisted of seven polypeptides with apparent molecular weights 15.442 kDa. It contains 954 mg/l which is second highest whey protein after α-lactalbumin. It is major protein for anti-cancer activities as well as inhibition of lipase (Ibrahim *et al.*).

Lactoferrin

Lactoferrin is glycoprotein and iron binding protein which protect over bodies again bacterial action giving bacteriostatic and bactericidal effect. Camel lactoferrin has 91.6% sequence similarity with bovine or human lactoferrin.

It contained a higher level (0.22 mg/ml) of lactoferrin compared to the other species except humans. Camel lactoferrin has 689 amino acid residues, a molecular weight of 75.3 kDa, and an isoelectric point of pH 8.63. Camel Lactoferrin has been discovered to simultaneously perform the two essential tasks of iron scavenging (lactoferrin) and iron release (transferrin). Antimicrobial activity against the Gram-negative bacterium *E. coli* is higher than for other orthologues.

Lactoperoxidase

Lactoperoxidase is oxidoreductase enzyme which generally found in saliva, tears and milk. It contributes non immune host defense system provide bactericidal effect against gram negative bacteria. Lactoperoxidase system in which hydrogen peroxide (H₂O₂) is reduced, and a halide, for example, iodide (I⁻) or bromide (Br⁻) for example, thiocyanate (SCN⁻), is subsequently oxidized (Ferrari *et al.*, 1997) by produced compound OSCN⁻ and OHSCN generating free SH groups in cytoplasmic membrane through it gives antimicrobial activities especially gram negative bacteria. Natural substrates of lactoperoxidase in milk are thiocyanate and iodide, of which milk contains trace amounts. Camel milk lactoperoxidase is a monomeric protein, which has 79.3% sequence similarity to human myeloperoxidase and 79.2% sequence similarity to human eosinophil peroxidase. The isoelectric point of camel lactoperoxidase was 8.63, whereas in bovine milk it was found pH 7.90 (Dull *et al.*, 1990) [10]. LP has 611 amino acids and 69.3 kDa MW. Camel LP enzyme even more heat stable than the ruminant variants.

Insulin

Camel milk is considered best choice for overcoming pathophysiologic complications and in providing the beneficial nutritional treatment especially for diabetes patients. Insulin is small protein or peptides hormone which regulate blood glucose level. It contain four times higher insulin (52 unit/liter) than bovine milk. Camel milk Insulin is lower MW comparable to insulin which mimics interaction of insulin with their receptors. It is packaged in nanoparticles smaller in size that allow it to pass easily through stomach and allows its entry to circulatory system act proper blood sugar regulation. It also inhibits the elevation of hormones, TNF-α and TGF-β1 levels which are

produced in response to Diabetes. Whey protein in camel milk act as anti-oxidant which help in healing process

reduce during diabetes (Aqib *et al.*, 2019) [3].

Table 9: Studies encompassing antidiabetic properties of camel milk insulin

Researcher	Model of Study	Duration	Decrease % in Blood glucose level
Khan, Alzohairy, and Mohieldein (2013)	Rats	4 weeks	54.76
El-Sayed, Al-Shoeibi, El-Ghany, and Atef (2011)	Human	3 month	22.22
Rajendra P Agrawal <i>et al.</i> (2007)	Human	12 month	13

Effect of different processing on camel milk protein

Different studies showed processing of camel milk is difficult compare to bovine milk mainly due compositional difference related to protein. Camel milk observed to be have poorer heat stability as well coagulation properties which directly affect product manufacturing. Properties of the milk proteins most influences or affected by technologically process including pasteurisation, sterilisation, fermentation, and cheese making. In all processes, heating is mainly used for preservation of camel milk and its products which affect the protein stability mainly affects its structure.

Heating

Heat treatment is an integral part of the dairy processing industry as it is essential for destroying spoilage and pathogenic microorganisms, extending the milk's shelf-life, and ensuring its safety for human consumption (Felfoul *et al.*, 2016; Yirda, Eshetu, & Babege, 2020) [19, 57]. Different process used mainly low heat and high heat treatment given *e.g.*, Pasteurization, UHT, Sterilization etc. In camel milk alkaline phosphatase enzyme inactive at higher temperature compare with bovine milk so its not used as a indicator to check the efficiency pasteurization. γ -glutamyl transferase (GGT) is used as a potential indicator for a proper pasteurization process of camel milk because it is destroyed between 10 to 20 minutes at 72 °C (Wernery, 2007) [55].

Heating effect on protein

Heat treatments affect the protein stability and functional properties of milk. As increase in temperature causes denaturation of whey proteins which leads to flocculation, protein sedimentation, gelation and aggregation with other unfolded monomer protein. (Tolkach & Kulozik, 2007) [54]. It is unstable at heating temperature of 120 °C to 130 °C at all pH values (6.5-7.1) and coagulated in 2-3 min compare to 40 min in bovine milk.

Effect on whey protein

This process particularly affects the protein which contributes denaturation of protein. Whey proteins from camel are more heat resistant than bovine milk proteins in order of α -lactalbumin > β -lactoglobulin > serum albumin. The degree of denaturation for camel milk whey proteins observed to be 32 to 35% at 80 °C and 47 to 53% at 90 °C versus 70 to 75% at 80 °C and 69% denaturation of IgG (Alhaj *et al.*). During heating changes occur in protein structure (unfolding) identified heated milk at 63 °C ranged from 15%-61% and at 98 °C from 79%-98% (Benabdelkamel *et al.*, 2017) [5]. Camel whey protein mainly has more stability in presence of metaloprotein which provide structure stability. On Heating at 90 °C/5min; 67% of camel milk α -lactalbumin remained intact compared with only 5% of α -lactalbumin in bovine milk. Felfoul *et al.* (2017) [20] reported that heating camel milk at 80 °C for 60

min induced a complete destruction of α -la and PGRP and a decrease of 42% of serum albumin concentration.

Effect on casein

Camel milk caseins are less stable than bovine milk caseins at higher temperatures due to variation in protein molecular properties (less k-casein). Camel milk k-casein is highly liable to heat as it is depleted at temperatures above 100 °C due exposure to internally buried amino-acid residues. Camel milk α _S-casein and β -casein are also affected by high heating temperatures but they are more stable than k-casein (Clement, 2018) [8]. Largely heating effect on hydrophobicity of camel β -casein. Heat-treated camel β -casein was found to possess greater abilities to form softer emulsions under acidic conditions (Ellouze *et al.*, 2021) [16].

Protective protein

Heating of camel milk at 65 °C/30 min has no significant effect on lysozymes and lactoferrins; however, a significant loss occurs in IgG activity. The activity of IgG in camel milk observed to be 69% where in cow and buffalo it completely lost activities at 75 °C/30. Lactoferrin lost 58% their activity at 85 °C for 30 minutes. Protective proteins, the order of heat resistance found was lysozyme > lactoferrin > IgG.

Camel milk has the poorer heat stability, due to:

- The lesser amount of κ -casein and the lack of β -lactoglobulin (Kappeler, 1998) [32], which are important in milk stabilization.
- The salt balance (ratio of Ca and Mg; citrate and phosphate) due to citrate level in camel milk is lower than that in cow milk (El-Agamy, 2000; Farah and Ruegg, 1989) [13, 18].

Coagulation

The coagulation of milk proteins depends upon the type of coagulant as well as the nature and composition of casein. Different coagulants such as proteolytic enzymes, acid have been used for milk coagulation during manufacturing of cheese. In cheese mainly use proteolytic enzyme derived from animal, plant, microbial sources. Manufacturing of cheese is challenging. RCT of camel milk cheese is two to four time higher compare to bovine milk cheese (Ayush *et al.*, 2022) [41].

Enzymatic coagulation of milk by proteolytic enzymes occur in mainly in two steps. κ -CN prevents micelle aggregation by steric hindrance and charge repulsion. In first step is characterized by hydrolysis of κ -CN in that C-terminal part is specifically cleaved during the enzymatic reaction at a hydrophobic cleavage site, which is Phe105-Met106 in cow κ -CN. In the second step of the renneting process, an exponential increase in coagulation of casein micelles is found. Aggregation starts when 60-80% of κ -CN is cleaved. The reduction of pH and addition of Ca++

increases curd firmness (Dalglish, 1992) [9]. In camel milk action of chymosin differ it selectively cleaves at the Phe⁹⁷-Ile⁹⁸ bond. During enzymatic action histidine residues in the sequence His98 to His102 of cow milk κ -CN are replaced by more basic amino acid arginine residues in camel milk κ -

CN. Chymosin not effectively hydrolysis camel k-CN. Proline residue may help to stabilise the k-CN conformation in the active site cleft of camel chymosin, which is different from the conformation of cow milk -CN in the cleft of bovine chymosin.

Camel:	Arg ⁹⁰ – Pro – Arg – Pro – Arg – Pro – Ser – Phe ⁹⁷ – Ile ⁹⁸ – Ala – Ile – Pro – Pro – Lys – Lys ¹⁰⁴
Cow:	His ⁹⁸ – Pro – His – Pro – His – Leu – Ser – Phe ¹⁰⁵ – Met ¹⁰⁶ – Ala – Ile – Pro – Pro – Lys – Lys ¹¹²

Camel milk cheese have a weak curd formation and soft gel texture compared bovine milk cheese. In Figure shows the difference between camel milk and bovine milk fresh model cheeses produced by chymosin enzyme and acidification

through citric acid. Camel milk cheese have soft and smooth compared to those produced from bovine milk due to variation in and more RCT in camel cheese milk cheese.

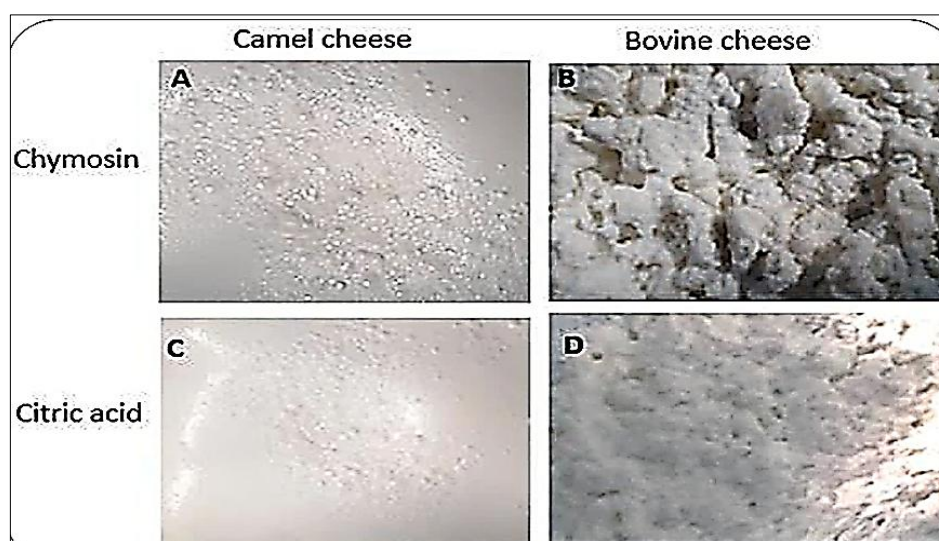


Fig 3: Cheese from camel and bovine produced by using chymosin and acid

Reason for weak coagulation

The low concentration of κ -casein in the milk and the larger casein micelles size have been primarily reason for the softness of camel milk cheeses. Low κ -casein: β -casein ratio (≈ 0.05 in camel milk vs. ≈ 0.33 in Bovine milk). Large casein micelles (260-300 nm) with reduced surface area has been associated with increased RCT which reduced cheese curd firmness and lower the overall quality of cheese (Glatz *et al.*, 2010) [23]. Other remarkable difference between Camel milk and bovine milk whey proteins is that Camel milk lacks β -lg which has important implications on milk functional properties mainly through its heat-induced association with κ -casein. More amount of protective proteins, *e.g.*, lysozyme, lactoferrin, and lactoperoxidase have antimicrobial properties and have been speculated to slow bacterial growth in camel milk (El Sayed *et al.*, 1992) [12].

Improved cheese coagulation and gelling properties

Hattem *et al.* found a synergistic impact between the addition of CaCl₂ up to 20 mg/100 ml of camel milk and thermal treatment of camel milk in lowering RCT using bovine chymosin. Different method are used for improving camel milk cheese gel strength. Using HPP process (200-400 MPa) mixture of different species milk as well as using microbial enzyme such that microbial transglutaminase (cross

linking enzyme) improve coagulation properties as well as reduced RCT time (Mbye1 *et al.*) Recombinant camel chymosin production which is derived from gene in a strain of *Aspergillus niger* now also used.

Ultrasonication

Ultrasonication is an emerging nonthermal preservation technology for the processing of dairy products that is widely used owing to its low cost and ease of operation. It affect tertiary and quaternary structures of proteins, which facilitates accessibility of enzymes for hydrolysis of proteins and release of peptides (Ozuna *et al.*, 2015.) [46] Improve the release of bioactive peptides. Increased antioxidant and angiotensin converting enzyme inhibitory activities.

Techno-functional properties of camel milk protein

Functional properties are those qualities or characteristics excluding nutrition, that determine their satisfactory use in food products. These characteristics could include mouthfeel, viscosity, structure and appearance. Milk proteins influence functionality that provide desirable textural or other attributes changes to the finished product. In techno functional properties include solubility, gelling, foaming and emulsification. Camel milk protein is less soluble than bovine milk protein.

Foaming

Foams are most commonly formed by mechanically dispersing air into a solution containing surface-active agents. Colloidal systems where air bubbles created are stabilized by a matrix composed of surface active agents of milk (*i.e.*, protein). Camel milk protein have better foaming capacity compare to bovine milk due presence of higher amount of β -casein (Hailu *et al.*, 2016) [25]. It is also rather surface active as a result of its amphipathic nature and plasmin hydrolysed bovine β -casein has shown improved foam forming and stabilising properties compared to its intact form (Caessens *et al.* 1997) [7]. Laleye *et al.* (2008) [38] reported that camel milk whey can form stable foams at pH 7 which useful for food formulation. Better foaming capacity values (~138%) of camel milk than bovine milk (~115%) at 20 °C.

Emulsification

Emulsification is heterogeneous systems formed by dispersing one or more phases in a continuous phase and they can be stabilized by incorporating surface-active agents. It mainly related oil-water interface. Due to more amount of β -casein amphiphilic nature attributes higher emulsification capacity (Esmaili *et al.*).

Gelling

The gelling properties of whey proteins are due to unfolding and denaturation followed by aggregation (Foegeding *et al.*, 2002) [22]. Protein-protein & protein-water interactions are balanced that 3-D network or gel was formed. In camel milk due to absence of β -lactoglobulin and less amount of κ -casein weak gel form mainly related β -lg and κ -casein interaction and form weak gel.

Functionality improved using hydrolysis process. Camel milk protein hydrolysates reported higher techno-functional properties compare to unhydrolyzed camel milk proteins. Enzymatic hydrolysis of protein release peptides with lower MW, different hydrophobicity and solubility properties, and a greater number of ionisable groups which improves the functionality. Endo-peptidase enzymes hydrolyze proteins rapidly, which reduces the amount of free amino acids for improved bioavailability (Foegeding *et al.* 2002) [22]. Camel milk protein highly degraded by pepsin; resistant to chymotrypsin & trypsin (Saliha *et al.*; Shamsi *et al.*). Other than enzymatic hydrolysis by using fermentation derived bioactive peptide also improve functionality such as ACE inhibitory and antioxidant activities. Camel milk peptides have higher bioavailability due more hydrolysis of protein presence of β -casein.

Nutritional and therapeutic properties of camel milk

Camel milk become new emerging super food aspect related to medicinal as well as therapeutical value. Camel milk has high nutritional value and has many components and properties homologous to human milk; thus, it can be a good replacement for human milk. In that main camel milk protein seek more attention due to uniqueness and functionality. It have the satisfactory quality balance of essential amino acids as well as ratio of essential amino acid and nonessential amino acid ratio for human diets for proper protein utilization. Nowadays camel milk has potential use related to serve disease including diabetes, Autism, allergies (Kumar, 2015). IGs of camel milk protein function in the treatment of complex developmental neurological disorder

(Autism). It have better digestibility compare to bovine milk due higher whey protein to casein ratio or lower casein to whey protein ratio (76:24).

Table 10: Nutritional value of camel milk protein

1 cup (245 g) of camel milk intake contains	RDA	
	Man	Women
Energy (kcal) 163	2300	2200
Protein (g) 7.9	63.0	50.0
Posati and Orr (1976); Podrabsky (1992) [49]		

Camel milk is rich in nutritional and functional properties. Rather than nutritional; it's have additional functional properties and therapeutical value including Antiallergenic, Antioxidative, Antimicrobial, Antidiabetic and ACE inhibitory properties.

Antiallergenic properties

Adults and children are suffering from different food allergies in world. In infancy and early childhood, cow's milk allergy is considered the most dominant food allergy (Rona *et al.*, 2007) [50] which mainly related to protein especially major protein. In alternative of that camel milk which contribute importance source reduce allergy or making less allergenic due absence of major allergen β -lg (Merin *et al.*, 2001) [39] and presence of immunoglobulin. Antiallergenic property of Camel milk also is due to the similar protein profile to human mother's milk in lacking β -lg and higher proportion of α -lactalbumin (Mojtahedi, Izadi, Seirafi, Khedmat, & Tavakolizadeh, 2018) [42].

Antioxidative properties

Reactive oxygen species is an aspect of oxidative stress which are associated with many diseases such as rheumatoid arthritis, diabetes, inflammation, atherosclerosis and cancers. Thus, the need for naturally occurring antioxidants prevention against free radical generation. In camel milk protein main Lactoferrins (LF) which improve antioxidant ability by scavenging free radicals; also give antiaging properties other than camel milk protein higher α -lactalbumin which rich in antioxidant amino acid (Salami *et al.*, 2009) [51]. Bioactive peptides with lower molecular weights pauses antioxidant activity. Purified and identified two novel peptides (NV-13 and KQ-15) from camel milk proteins and examined antioxidant properties of these peptides (Homayouni-Tabrizi *et al.*, 2016) [28].

Antidiabetic properties

Diabetes is a group of metabolic disorders associated with chronic hyperglycemia in the blood due to a work in insulin secretion, insulin function. Primary treatment for type 1 diabetes is insulin, camel's milk plays a vital role in maintaining the pancreatic β -cell's function. It improves obesity, inflammation, wound healing and oxidative stress damages as diabetes complications (Agrawal *et al.*, 2013). Camel milk may prepare about 60% of the insulin in diabetic patients (Shori *et al.*, 2015) [52]. Hormones like glucagon and glucose-dependent insulinotropic polypeptides, such as gastric inhibitory polypeptide (GIP) and glucagon-like peptide-1 (GLP1), as well as enzymes such as the endoprotease dipeptidyl peptidase IV (DPP-IV) and its proteolytic effects on GIP and GLP-1, have a crucial role in the control of insulin synthesis and secretion by the pancreases (Ayoub *et al.*, 2018) [4].

ACE inhibitory properties

Camel milk derived Bioactive peptides from camel milk has ACE inhibitory activity. Ile-Pro-Pro liberated during GI digestion of camel milk κ -casein which has hypotensive effect. Proline amino acid in structure of formed peptides has significant role in lowering of blood pressure. Tripeptides Val-Pro-Pro & Ile-Pro-Pro which are inhibitors of angiotensin converting enzyme properties of peptides that regulate blood pressure (Dziuba B., & Dziuba, 2014) [11].

Autism

Autism spectrum neurological disorder is of behavioral symptoms in affected children distinguished by emotional confusion, symbolic behavior, difficulties with social interactions & verbal and nonverbal conversations. Ig and lactoferrin of camel milk protein function in the treatment of this complex developmental disorder. Decrease of Autism

symptoms in children aged 5-14 years by regular 14 day consumption of pasteurized camel milk (0.5 l/d) (Ozkaya, 2013) [45]. Main in autism related oxidative stress which reduce camel milk protein. Effect of camel milk supplementation on oxidative stress biomarkers such as myeloperoxidase, superoxide dismutase (SOD), and glutathione in children with autism.

Antimicrobial properties

Camel milk contains protective proteins like Igs and LF. Isolated LF from camel milk through the disruption of cell membrane had the maximum antibacterial activity against this food-borne pathogen. Peptides generated by enzymatic digestion of LF have an antimicrobial potential (Abbas *et al.* 2013) [1]. The highest activity against *E. coli* O157:H7 compared to LFs isolated from other milk (Conesa *et al.*).

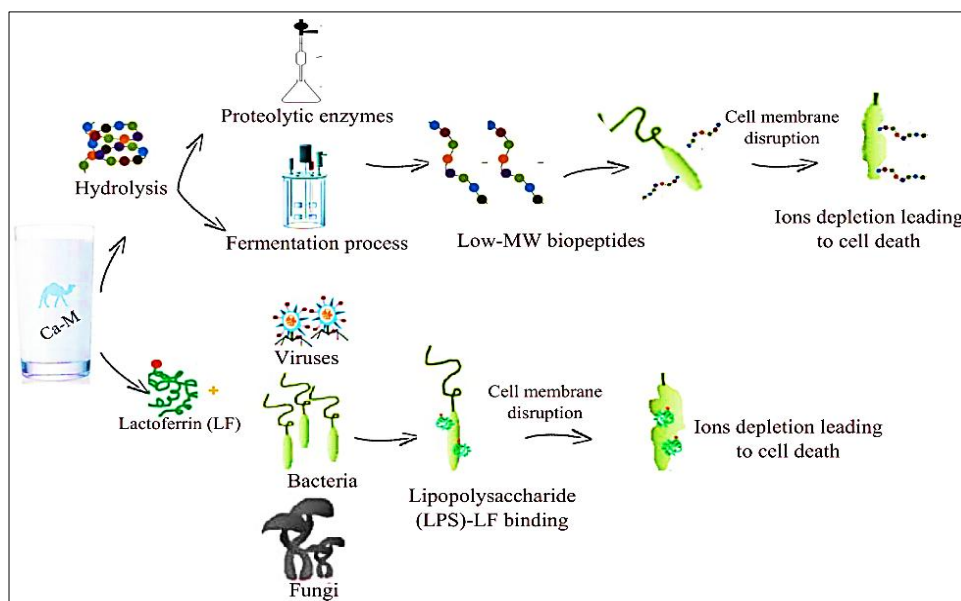


Fig 4: The antimicrobial mechanism of Camel milk proteins (e.g., LF) and its hydrolysates

Anticancer activities: Camel milk inhibited both human hepatoma and breast cancer cell survival and proliferation through the activation of both the extrinsic and intrinsic apoptotic pathways (Korashy *et al.*, 2012) [36]. Antitumor fraction from whey proteins of camel milk which have eradicate epithelial cell lines of human esophageal carcinoma (Nakamura *et al.*, 2013) [43]. Antitumor fraction from whey proteins (LF) of camel milk which was able to eradicate the epithelial cell lines of human esophageal carcinoma (khan *et al.*, 2021) [34]. Interaction of oleic acid and hydrophobic core of α -lactalbumin in a molten globule state which improve the apoptotic activity to eradicate selective tumour cells (Yang *et al.*, 2018) [56].

Conclusion

Camel milk is rich in health-beneficial substances with novel protein which contribute functionality as well therapeutical potential. The composition and molecular properties of camel milk protein is different from bovine milk and similarity with human milk due absence of β -Ig and contains more protective proteins. In techno-functional properties it has better foaming as well as emulsification capacity compare to bovine milk due to presence of more amount of β -casein. Camel milk whey protein are more

stable compare to bovine milk. It has produced weak gel during coagulation. Camel milk is considered an invaluable alternative source to cow milk. It has much less allergic effects than cow. Camel milk is an excellent candidate to improve the growth performance of infants and children. Camel milk has comparatively higher functional contribution to human health as a result of the unique composition of caseins and whey proteins (WAP, α -la, LF, PGRP-S, and IgG with the different variants of Ig).

References

1. Abbas S, Ashraf H, Nazir A, Sarfraz L. Physico-chemical analysis and composition of camel milk. *Int Researchers*. 2013;2:82-98.
2. Agrawal RP, Saran S, Sharma P, Gupta RP, Kochar DK, Sahani MS. Effect of camel milk on residual β -cell function in recent onset type 1 diabetes. *Diabetes Res Clin Pract*. 2007;77(3):494-495.
3. Aqib AI, Kulyar MFEA, Ashfaq K, Bhutta ZA, Shoaib M, Ahmed R. Camel milk insulin: pathophysiological and molecular repository. *Trends Food Sci Technol*. 2019;88:497-504.

4. Ayoub MA, *et al.* The molecular basis of the anti-diabetic properties of camel milk. *Diabetes Res Clin Pract.* 2018;146:305-312.
5. Benabdelkamel H, Masood A, Alanazi IO, Alzahrani DA, Alrabiah DK, AlYahya SA, Alfadda AA. Proteomic profiling comparing the effects of different heat treatments on camel (*Camelus dromedarius*) milk whey proteins. *Int J Mol Sci.* 2017;18:2-15.
6. Berhe T, Seifu E, Ipsen R, Kurtu MY, Hansen EB. Processing challenges and opportunities of camel dairy products. *Int J Food Sci.* 2017;2017:1-12.
7. Caessens PWJR, Gruppen H, Visser S, Van Aken GA, Voragen AGJ. Plasmin hydrolysis of β -casein: foaming and emulsifying properties of the fractionated hydrolysate. *J Agric Food Chem.* 1997;45:2935-2941.
8. Clement CD. Effect of heat treatment on camel milk proteins. Al-Ain: United Arab Emirates University; 2018.
9. Dagleish DG. The enzymatic coagulation of milk. In: Fox PF, editor. *Advanced dairy chemistry-1: proteins.* London: Applied Science Publishers; 1992. p. 579-620.
10. Dull TJ, Uyeda C, Strosberg AD, *et al.* Molecular cloning of cDNAs encoding bovine and human lactoperoxidase. *DNA Cell Biol.* 1990;9:499-509.
11. Dziuba B, Dziuba M. Milk protein-derived bioactive peptides in dairy products: molecular, biological and methodological aspects. *Acta Sci Pol Technol Aliment.* 2014;13:5-25.
12. El Sayed I, Ruppanner R, Ismail A, Champagne CP, Assaf R. Antibacterial and antiviral activity of camel milk protective proteins. *J Dairy Res.* 1992;59:169-175.
13. El-Agamy EI. Effect of heat treatment on camel milk proteins with respect to antimicrobial factors: a comparison with cow and buffalo milk proteins. *Food Chem.* 2000;68:227-232.
14. El-Agamy EI. Bioactive components in camel milk. In: Young WP, editor. *Bioactive components in milk and dairy products.* Vol 107. Iowa: Blackwell Publishing; 2009. p. 159-192.
15. El-Agamy ESI. Camel milk. In: Park YW, Haenlein GFW, Wendorff WL, editors. *Handbook of milk of non-bovine mammals.* West Sussex: John Wiley & Sons; 2006. p. 409-480.
16. Ellouze M, Vial C, Attia H, Ayadi MA. Effect of pH and heat treatment on structure, surface characteristics and emulsifying properties of purified camel β -casein. *Food Chem.* 2021;365:130421.
17. FAOSTAT. Food and Agriculture Organization of the United Nations. Rome: FAO; 2019.
18. Farah Z, Ruegg MW. The size distribution of casein micelles in camel milk. *Food Microstruct.* 1989;8:211-216.
19. Felfoul I, Beaucher E, Cauty C, Attia H, Gaucheron F, Ayadi MA. Deposit generation during camel and cow milk heating: microstructure and chemical composition. *Food Bioprocess Technol.* 2016;9:1268-1275.
20. Felfoul I, Jardin J, Gaucheron F, Attia H, Ayadi MA. Proteomic profiling of camel and cow milk proteins under heat treatment. *Food Chem.* 2017;216:161-169.
21. Ferrari RP, Ghibaudi EM, Traversa S, *et al.* Spectroscopic and binding studies on the interaction of inorganic anions with lactoperoxidase. *J Inorg Biochem.* 1997;68:17-26.
22. Foegeding EA, Davis JP, Doucet D, McGuffey MK. Advances in modifying and understanding whey protein functionality. *Trends Food Sci Technol.* 2002;13:151-159.
23. Glantz M, Devold T, Vegarud G, Månsson HL, Stålhammar H, Paulsson M. Importance of casein micelle size and milk composition for milk gelation. *J Dairy Sci.* 2010;93:1444-1451.
24. Habib HM, Ibrahim WH, Stock RH, Hassan HM. Camel milk reduces the proliferation of colorectal cancer cells and exerts antioxidant and DNA damage inhibitory activities. *Food Chem.* 2013;141(1):148-152.
25. Hailu Y, Hansen EB, Seifu E, Eshetu M, Ipsen R, Kappeler S. Functional and technological properties of camel milk proteins: a review. *J Dairy Res.* 2016;83(4):422-429.
26. Hinz K, Connor PM, Huppertz T, Ross RP, Kelly AL. Comparison of the principal proteins in bovine, caprine, buffalo, equine and camel milk. *J Dairy Res.* 2012;79(2):185-191.
27. Ho TM, Zou Z, Bansal N. Camel milk: nutritional value, heat stability and potential food products. *Food Res Int.* 2021;153:110870.
28. Homayouni-Tabrizi M, Shabestarin H, Asoodeh A, Soltani M. Identification of two novel antioxidant peptides from camel milk and their impact on superoxide dismutase gene expression. *Int J Pept Res Ther.* 2016;22(2):187-195.
29. Kamal-Eldin A, Ayyash M, Sobti B, Nagy P. Camel milk. In: McSweeney PLH, McNamara JP, editors. *Encyclopedia of dairy sciences.* 3rd ed. San Diego: Academic Press; 2022. p. 504-513.
30. Kappeler SR, Heuberger C, Farah Z, Puhani Z. Expression of the peptidoglycan recognition protein (PGRP) in the lactating mammary gland. *Journal of Dairy Science.* 2004;87:2660-2668.
31. Kappeler S. Compositional and structural analysis of camel milk proteins with emphasis on protective proteins [PhD thesis]. Zurich (Switzerland): Swiss Federal Institute of Technology (ETH); 1998.
32. Kappeler S. Compositional and structural analysis of camel milk proteins with emphasis on protective proteins [doctoral dissertation]. Zurich (Switzerland): ETH Zurich; 1998.
33. Kappeler SR, Farah Z, Puhani Z. 5'-Flanking regions of camel milk genes are highly similar to homologue regions of other species and can be divided into two distinct groups. *Journal of Dairy Science.* 2003;86(2):498-508.
34. Khan MZ, Xiao J, Ma Y, Ma J, Liu S, Khan A, *et al.* Research development on antimicrobial and antioxidant properties of camel milk and its role as an anticancer and antihepatitis agent. *Antioxidants.* 2021;10(5):788.
35. Konuspayeva G, Faye B, Loiseau G, Levieux D. Lactoferrin and immunoglobulin contents in camel milk (*Camelus bactrianus*, *Camelus dromedarius* and hybrids) from Kazakhstan. *Journal of Dairy Science.* 2007;90:38-46.
36. Korashy HM, Maayah ZH, Abd-Allah AR, El-Kadi AO, Alhaider AA. Camel milk triggers apoptotic signaling pathways in human hepatoma HepG2 and breast cancer MCF7 cell lines through transcriptional mechanisms. *Journal of Biomedical Biotechnology.* 2012;2012:1-9.

37. Kumar N. Camel milk: Natural medicine—boon to the dairy industry. *Dairy Foods*. 2015 Dec 22.
38. Laleye LC, Jobe B, Wasesa AAH. Comparative study on heat stability and functionality of camel and bovine milk whey proteins. *Journal of Dairy Science*. 2008;91:4527-4534.
39. Merin U, Bernstein S, Bloch-Damti A, Yagil R, Van Creveld C, Lindner P, *et al.* A comparative study of milk serum proteins in camel (*Camelus dromedarius*) and bovine colostrum. *Livestock Production Science*. 2001;67(3):297-301.
40. Mirmiran P, Ejtahed HS, Angoorani P, Eslami F, Azizi F. Camel milk has beneficial effects on diabetes mellitus: A systematic review. *International Journal of Endocrinology and Metabolism*. 2017;15(2):e42150.
41. Mohamed H, Ayyash M, Kamal-Eldin A. Effect of heat treatments on camel milk proteins: A review. *International Dairy Journal*. 2022;133:105404.
42. Mojtahedi SY, Izadi A, Seirafi G, Khedmat L, Tavakolizadeh R. Risk factors associated with neonatal jaundice: A cross-sectional study from Iran. *Open Access Macedonian Journal of Medical Sciences*. 2018;6(8):1387-1393.
43. Nakamura T, Aizawa T, Kariya R, Okada S, Demura M, Kawano K, *et al.* Molecular mechanisms of the cytotoxicity of human α -lactalbumin made lethal to tumor cells (HAMLET) and other protein-oleic acid complexes. *Journal of Biological Chemistry*. 2013;288(20):14408-14416.
44. Omar A, Harbourne N, Oruna-Concha MJ. Quantification of major camel milk proteins by capillary electrophoresis. *International Dairy Journal*. 2016;58:31-35.
45. Ozkaya TB. Transition from pervasive developmental disorders to autism spectrum disorder: Proposed changes for DSM-5. *Current Approaches in Psychiatry*. 2013;5(2):127-139.
46. Ozuna C, Paniagua-Martínez I, Castaño-Tostado E, Ozimek L, Amaya-Llano SL. Innovative applications of high-intensity ultrasound in the development of functional food ingredients: Production of protein hydrolysates and bioactive peptides. *Food Research International*. 2015;77:685-696.
47. Pal M, Sabir M. Major milk-borne microbial diseases of camels. *Haryana Veterinarian*. 2015;54:93-98.
48. Poltronieri P, Cappello MS, D'Urso OF. Bioactive peptides with health benefit and their differential content in whey of different origin. In: Benitez RM, Ortero GM, editors. *Whey types, composition and health implications*. Hauppauge (NY): Nova Publishers; 2012. p. 153-168.
49. Posati LP, Orr ML. *Composition of foods: Dairy and egg products*. Washington (DC): USDA-ARS, Consumer and Food Economics Institute; 1976. Agriculture Handbook No. 8-1. p. 77-109.
50. Rona RJ, Keil T, Summers C, Gislason D, Zuidmeer L, Sodergren E, *et al.* The prevalence of food allergy: A meta-analysis. *Journal of Allergy and Clinical Immunology*. 2007;120(3):638-646.
51. Salami M, Yousefi R, Ehsani MR, Razavi SH, Chobert JM, Haertlé T, *et al.* Enzymatic digestion and antioxidant activity of native and molten globule states of camel α -lactalbumin: Possible significance for infant formula. *International Dairy Journal*. 2009;19(9):518-523.
52. Shori AB. Camel milk as a potential therapy for controlling diabetes and its complications: A review of *in vivo* studies. *World Journal of Pharmaceutical Sciences*. 2015;23(4):609-618.
53. Shori AB. Camel milk as a potential therapy for controlling diabetes and its complications: A review of *in vivo* studies. *Journal of Food and Drug Analysis*. 2015;23(4):609-618.
54. Tolkach A, Kulozik U. Reaction kinetic pathway of reversible and irreversible thermal denaturation of β -lactoglobulin. *Le Lait*. 2007;87:301-315.
55. Wernery U. Camel milk—new observations. In: Gahlot TK, editor. *Proceedings of the International Camel Conference*. Bikaner (India): CVAS; 2007. p. 200-204.
56. Yang J, Dou Z, Peng X, Wang H, Shen T, Liu J, *et al.* Transcriptomics and proteomics analyses of anticancer mechanisms of TR35, an active fraction from Xinjiang Bactrian camel milk, in esophageal carcinoma cells. *Clinical Nutrition*. 2018.
57. Yirda A, Eshetu M, Babege K. Current status of camel dairy processing and technologies: A review. *Open Journal of Animal Sciences*. 2020;10:362-377.
58. Zhao DB, Bai YH, Niu YW. Composition and characteristics of Chinese Bactrian camel milk. *Small Ruminant Research*. 2015;127:58-67.
59. Zou Z, Bauland J, Hewavitharana AK, Al-Shehri SSA, Duley JA, Cowley DM, *et al.* A sensitive high-throughput fluorescent method for determination of lactoperoxidase activity in milk and comparison among human, bovine, goat and camel milk. *Food Chemistry*. 2021;339:128090.
60. Haenlein M, Libai B. Seeding, referral, and recommendation: Creating profitable word-of-mouth programs. *California Management Review*. 2017 Feb;59(2):68-91.
61. Bujang MA, Omar ED, Baharum NA. A review on sample size determination for Cronbach's alpha test: a simple guide for researchers. *The Malaysian journal of medical sciences: MJMS*. 2018 Dec 28;25(6):85.