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Prevalent and Exceptional Milk Species with the Possibilities of Their Applications in Famous Dairy Products

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Abstract

Milk is considered as one of the first foodstuffs that are given to the neonates of various species. Mammalian milk composition grants a unique natural fluid that meets the requirements for every single species. Variation in different milk proteins makes each type of milk suitable for a particular purpose. Dairy products are deeming a significant food source for several consumers categories. The most common ruminant's species milk used for dairy manufacturing for a long time are cow, buffalo, goat and sheep. Recently, many researches have focused on some rare animal species which had diverse positive effect on human health. These species are camel, mare, donkey and yaks. This research is an overview and comparison between milk composition & protein types and ratio in different mammalian like human, cow, buffalo, goat, sheep, camel, mare and donkey milk. Furthermore, comparing digestibility of these milk types, and highlighting the possibility of producing some dairy products from unusual milk species to gain the benefits of its biological properties. Moreover, the alternative methods that can be used to deal with the production problems when using the non-common milk species.

Keywords: Milk Protein Species; Human Milk; Camel Milk; Some Dairy Products; Fermented Milk

Introduction

Milk which secreted at the first birth of mammalians and its products has been consumed by billions of people every day around the world. It considered a balanced diet due to it gives energy and necessary nutrients for the neonate at the weaning erpio [1,2]. It has a various composition according to the requirements of each type. Many bioactive components in milk support meeting the nutritional demands of consumers besides preventing plentiful disorders [1]. The main component in milk is moisture which about 85-90% and all components are less than moisture. The responsibility for the development of the brain and nervous system lies with the disaccharide sugar which is composed of glucose & galactose and called lactose [3].

The most widespread milk species is cow milk which comprises about 85% of worldwide production. The ratios of the other milk species types which are buffalo, goat, sheep and camel milk were (11, 2.3, 1.4 and 0.2%) [4]. Furthermore, Roy, et al. [5] demonstrated that there is a lack of worldwide data on domestic animal species like horses, donkeys, and yaks in terms of their achievement to milk production universally, which is less than 0.1%. Some sources have suggested that reindeer, llama, and zebra milk have been considered as prospective mammalians. The proportion of these lesser-known milk species has increased from approximately 9% in 1961 to 19% in 2018 of the overall world milk production.

Milk proteins have many of beneficial physiological properties, including providing amino acids and nitrogen to nourish small mammals. The short chain amino acids which are formed of 2-20 acids; is called bioactive peptides; their state is inactive while part of the parent protein sequence. However, when they are released through in vitro processing or during gastrointestinal digestion, they become active and act as regulatory compounds, promoting positive effects on bodily functions. These bioactive peptides have the potential to provide various health benefits such as fighting cancer, combating microbes, reducing high blood pressure, easing inflammation, lowering blood sugar levels, and regulating the immune system [1,6].

The most types of milk which used at the dairy manufacture are buffalo, goat, sheep, and camel and become more prevalent and gainful for manufacturers. Lately, large and medium dairy factories, as well as small producers, have tended to follow a new strategy in using un-common milk species for producing several dairy outcomes. Furthermore, the relatively digestion and less allergenic of these species like goat, sheep, camel, horse, and donkey have taken into consideration than cow milk [5].

This review is an attempt to spot a light on the fundamental differences between milk species and their proteins composition. Digestibility of these milk types and try to highlight the possibility of producing some dairy products by non- prevalent milk to benefit with its biological properties.

Milk and Milk Proteins Definition

Milk is defined as a pale liquid that consists of milk proteins, fat, lactose, and a variety of vitamins & minerals as stated in free dictionary. The mammary glands of overripe female mammals generate milk through the process of lactation post childbirth. Colostrum milk which produces in the early days following birth; serves an important purpose in fulfilling the body's requirements, promoting bone development, preserving overall health and well-being by virtue of its diverse components [2,7,8]. As per the guidelines established by the "Codex Alimentarius Commission", a joint effort by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), who defined milk as the natural liquid produced by mammary glands of animals during milking sessions. Milk is distinguished by being either drunk directly or used in the manufacture of many products [9].

All the basic components of milk, namely fat, protein, lactose and ash, are present in all types of milk, but their proportions vary according to the animal kind, as shown in Table 1 [2,5,10]. Several factors are affected on these components' ratios such as breed, lactation stage, milking frequency, feed type, and environmental conditions. Furthermore, Figure 1 illustrated the protein ratios in milk from different species.

Milk g/100g	Total Dry Matter (TDM)	Fat	Protein	Lactose	Ash	Energy KJ/100g
Human	10-13	2.1-4.0	0.9-1.9	6.3-7.0	0.2-0.3	270-290
Mare	9-12	0.4-7.2	1.3-2.0	6.0-7.2	0.3-0.5	109-210
Donkey	8-12	0.3-1.8	1.4-2.0	5.8-7.4	0.3-0.5	160-180
Buffalo	16-17	5.3-15.0	2.7-4.7	3.2-4.9	0.8-0.9	420-480
Cow	-13	3.3-6.4	3.0-4.0	4.4-5.6	0.7-0.8	270-280
Goat	12-16	3.0-7.2	3.0-5.2	3.2-4.5	0.7-0.9	280-290
Ewe	18-20	4.9-9.0	4.5-7.0	4.1-5.9	0.8-1.0	410-440
Camel	11.9-15	2.4-6.0	2.4-4.2	3.5-5.1	0.69-0.9	241-328
Ilama	13.1	2.7-4.7	3.4-4.3	5.9-6.5	0.5-0.9	270-335
Yak	13.5-1804	5.3-9.5	4.2-5.9	3.3-6.2	0.4-1.0	381-429
Reindeer	20.1-27.1	10.2-21.5	7.5-13.0	1.2-4.7	1.2-2.7	554-843

Table 1: Milk composition of different animal species - interval values (minimum and maximum) reported in mentioned literatures**.**

Casien and whey proteins are the two main proteins which their ratios are varies among different mammalian species. This ratio in human milk is 40:60, equine milk is 50:50, while in cow, sheep, goat, and buffalo milk, are 80:20 according to the research by Roy D, et al. [5] in Table 2. Casein micelles consist of α Sl -casein (αSl -CN), αS2 - casein (αS2 -CN), β-casein, and k-casein. As well, whey proteins encompass significant fractions such as β-lactoglobulin (β-lg), α-lactalbumin (α-lac), blood serum albumin (BSA), immunoglobulins (Igs), proteoses and peptones (PP), lactotransferin, serotransferrin, osteopontins Vitamins, binding proteins, lactoferrin, and around 60 indigenous [11].

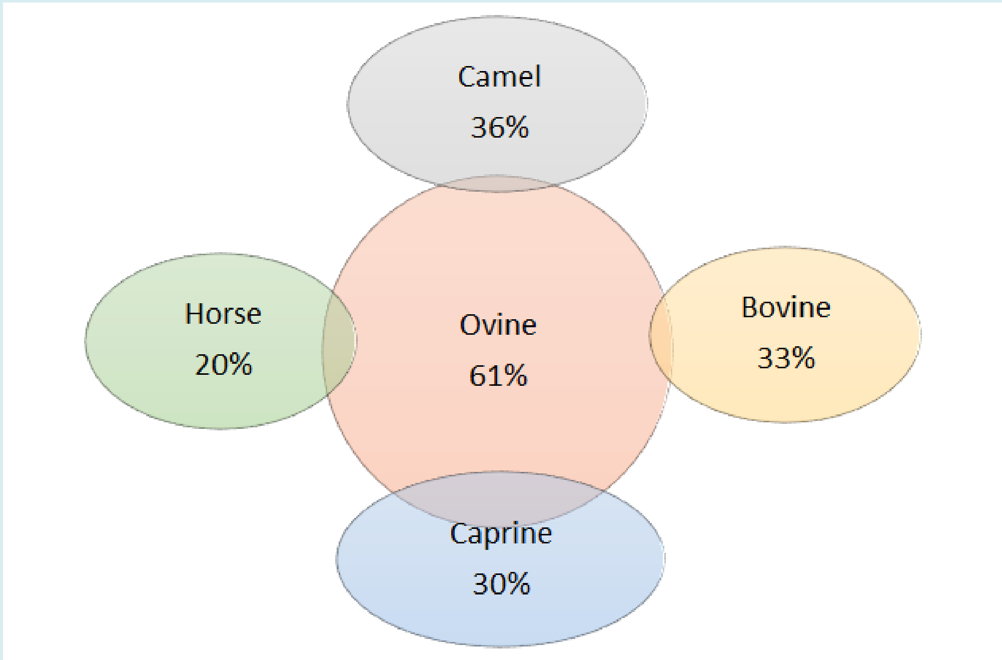

Figure 1: Milk proteins ratios in some mammalian's species.

Protein Fractions	Ruminants						Non-ruminants		Human
	Cow	Buffalo	Goat	Sheep	Deer	Camel	Horse	Donkey	
Total Casein	24.6–28	32–40	23.3-46.3	41.8-52.6	~57-84	22.1-26.0	9.4-13.6	6.4-10.3	2.4-4.2
Total Whey Proteins	5.5–7.0	6	3.7-7.0	10.2-16.1	~11-15	5.9-8.1	7.4-9.1	4.9-8.0	6.2-8.3
Casein-to-whey protein ratio	82:18	82:18	78:22	76:24	~80:20-85:15	73:27-76:24	52:48	56:44	29:71-33:67
Major Caseins									
αs_1-Casein	8–10.7	8.9	0-13.0	2.4-22.1	-	4.9-5.7	2.4	Present	0.77
αs_2-Casein	2.8–3.4	5.1	2.3-11.6	6	-	2.1-2.5	0.2	Present	Absent
β-Casein	8.6–9.3	12.6-20-9	0-29.6	15.6-39.6	-	14.4-16.9	10.66	Present	3.87
k-Casein	2.3–3.3	4.1-5.4	2.8-13.4	3.2-12.23	-	0.8-0.9	0.24	Present	0.14
Major Whey Proteins									
β-Lactoglobulin	3.2–3.3	3.9	1.5-5.0	6.5-13.5	-	Absent	2.55	3.3	Absent
α-Lactalbumin	1.2–1.3	1.4	0.7-2.3	1-1.9	-	0.8-3.5	2.37	1.9	1.9-3.4

Table 2: Protein profile (g L^{-1}) of milk from different mammalian species.

Additionally, milk proteins which take into consideration the building blocks of living tissues have all the essential amino acids and elements which human body cannot make [7]. Conversely, αs1-, αs2- and β-caseins are predominantly situated within the micelles, where they form connections with calcium phosphate nano-clusters through their phosphoserine domains [12]. Casein is a type of phosphoprotein that exists in a suspended state as colloidal molecules. These molecules have the ability to come together in a spherical form with a diameter ranging from approximately 50 to 500 nanometers. These structures are commonly known as 'Casein micelles', which are made up of smaller units known as sub-micelles Figure 2 by Anema [13]. The bonding between sub-micelles is facilitated by calcium bridges and hydrophobic interactions. Within the micelle structure, κ-Casein is predominantly located on the surface, specifically in the hydrophilic C-terminal region. These κ-caseins are grouped together in clusters, making them vulnerable to interaction with chymosin for further processing [14-16].

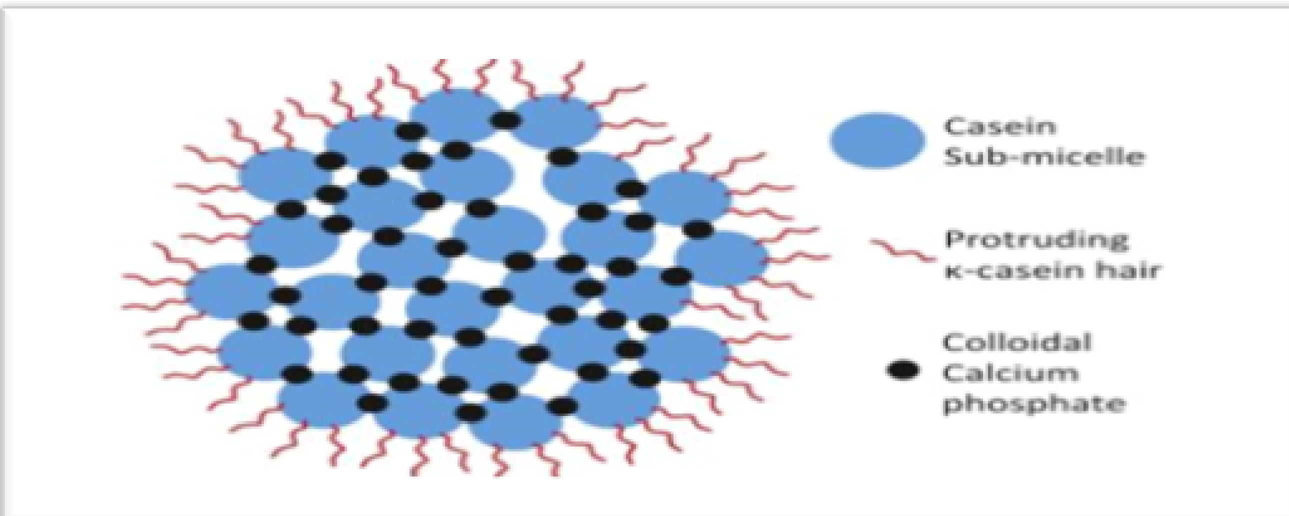

Figure 2: Casein micelle and sub-micelle (hairy model).

Total protein (TP) determines the market value of milk, the higher the TP value, the more money the producer will get. Here is an attempt to display the composition of different milk protein species:

Some Types of Milk Species

Human (Breast) Milk

According to the World Health Organization (WHO), the best way to breastfeed is to start early, exclusively breastfeed for the first 6 months, feed frequently, breastfeed for two years, and increase breastfeeding during times of illness [17]. Early initiation of breastfeeding means starting to breastfeed within one hour of childbirth. This practice has many benefits, such as boosting the baby's immune system, lowering diarrhea risk, and progress the overall child survival rates. At the first month of birth there were about 2.7 million newborns passed away in 2015 worldwide, with more than a third of these deaths occurring on the first day. This number of deaths could be minimized to 33% when mothers practice early initiation of breastfeeding [17-20].

Several data had illustrated the impact of 12 months of lactation on obesity, blood pressure, type 2 diabetes with low risk of ovarian and breast cancers, decreases blood pressure and the rates of postpartum depression for mother. This practice had an impact on the sleep patterns of not only the children but also their mothers. It is important to highlight that breastfeeding through skin-to-skin contact can offer solace to both mothers and children in moments of tension or unease [21-25]. There are some diverse roles of breast milk proteins like aiding digestion, boosting the immune system, protecting against harmful bacteria, viruses, and yeasts, as well as supporting the growth and function of the gastrointestinal tract [26].

Globally, in 2022 it was assessed that the potential of breastfeeding saved 574 billion USD (0.7% of global Gross Domestic Product, GDP), and more than 10% of household's wages by not having to purchase infant formula [27]. Colostrum that rich in immunoglobin G; is the first milk formed in the beginning days after birth that is very paramount for protecting against newborns infections. It prevents many of bacterial, viral, fungal and protozoa infection for the babies. Some researches explained that children who didn't feed colostrum could suffered from various infections such as stunting, underweight, and wasting [17,28-30]. In general, colostrum has high ratios of growth factors and immunologic components such as secretory immunoglobulin A (sIgA), lactoferrin & leukocytes, and contains relatively low concentrations of lactose, lipids, and energy. So, it could be concluded that the substantial mission of colostrum is trophic and immunologic more than nutrition [30]. Hsu, et al. [31] indicated a shortage in secretory immunoglobulin levels, with a constant concentration in calcium, lactoferrin, and lysozyme based on the stage of lactation. Specifically, protein concentrations were noticeably elevated in extremely premature milk (less than 28 weeks) compared to moderately premature and full-term milk. In contrast to full-term milk, premature milk is distinguished by higher levels of immune proteins and lower levels of nutritive proteins [32]. However, breast milk protein which don't have fractions like αs1-casein, αs2-casein and β-lg; has low level compared to a high ratio of protein in cow milk which contained β-CN as the major casein fractions as shown in Table 3, but contain a high content of lactoferrin (LF). The exceptional digestibility rate of approximately 95%, along with its superior amino acid profile, establishes milk protein as a top-tier protein source in terms of quality [33,34], but contain a high content of lactoferrin (LF). It also owns high digestibility of ~ 95%, combined with a superior amino acid composition, makes milk protein a "high quality protein" [35].

Protein Types	Breast Milk (mg/ml)	Cow Milk (mg/ml)
αs1-casein	0	11.6
αs2-casein	0	3
β-casein	2.2	9.6
K-casein	0.4	3.3
γ-casein	0	1.6
β-lg	0	3
α-la	2.2	1.2
BSA	0.4	0.4
Ig	0.8	0.6
Lactoferrin	1.4	0.3
Lyzozyme	0.5	Traces

Table 3: Composition of the main proteins in breast and cow milk.

Bovine (Cow) Milk

Bovine milk the copious milk which consumed for thousands of years had been recorded in ceramic pieces dating back 7500 years [36]. Nevertheless, many high-producing dairy cows have the ability to effectively manage lactational issues while maintaining good health [37]. Milk composition alters between breeds of cows, but generally includes protein (both casein and whey proteins), fat, lactose, alongside extolled minerals and vitamins. The cow's milk protein is highly nutritious, as it is copious in essential amino acids such as leucine, isoleucine, valine, lysine, histidine, methionine, and phenylalanine. These amino acids contribute to various health functions and provide significant nutritional value [9].

Bovine proteins are assorting to 4 categories: caseins (including αS_1-, αS_2-, β- and k-caseins) and whey proteins, also renowned as serum proteins, which consist of different fractions as mentioned in table 4. Among these fractions, α-lactalbumin (α-La) acts as a component of lactose synthase and has antimicrobial and anticancer properties, while β-lactoglobulin (β-Lg) serves as an immunoglobulin carrier till colostrum formation. Bovine serum albumin (BSA) exhibits anticancer with immunomodulatory effects, and Lactoferrin (LF) is a glycoprotein with iron-binding capabilities similar to transferrin, along with antimicrobial, antiviral, immunomodulatory, antioxidant, and antitumor properties. Lysozyme also plays a role in antimicrobial defense, while immunoglobulins save the mammary gland from infections. Additionally, minor whey proteins such as proteose peptones (low molecular weight peptides derived from caseins), proteose peptone component3 (PP3), milk fat globule membrane (MFGM), and lacto-peroxidase exhibit antimicrobial and antioxidant properties Table 4 [9,38].

Protein Type	Concentration (g/L)
αs1-casein	10
αs2-casein	2.6
β-casein	9.3
K-casein	3.3
γ-casein	0.8
β-lg	3.2
α-la	1.2
BSA	0.4
Ig	0.8
Pp, 8F, 8S	0.5
PP3	0.3
Lactoferrin	0.1
Transferrin	0.1
MFGM	0.4
Total	33

Table 4: Protein ratios of bovine milk.

There is nearly 30-35 g protein/L in ordinary bovine milk, the ratio of this protein is divided into 80% for casein micelles and 20% for whey proteins. Milk protein can precipitate by lowing pH to 4.6 at 20°C or using chymosin enzyme into casein and whey proteins. It was recognized that there were 7 variants of αs_1-CN, 4 of αs_2-CN, 9 of β-CN and 6 of κ-casein. αs_1-, αs_2- and β-CN are called calcium sensitive fraction, whilst κ-casein is called "protective colloid" as it stabilizes casein micelles [33].

In the same vein, Brophy, et al. [39] expounded that four fractions of casein bovine milk which are αs_1-, αs_2-, β-, and κ-casein, aggregated into large colloidal micelles and also managed physicochemical properties of milk such as structure and stability.

Thus, improvement of milk characteristics could increase by growing casein concentration. As it known that κ-casein; which coats the surface of the micelles has a serious part in improving heat stability and enhancement the properties of cheese product. Further, good processing characteristics correlated with high content of β-case in which contain minimized rennet clotting time and boosted whey ejection.

As well as β-casein has two familiar variants (A_1 and A_2); A_1 has His67 whilst A_2 has Pro67. There had been known that many of biological effects can output from β-casein; the famous on is called casomorphin-7 between the position of 60 to 66 amino acid [40]. Compared to human, cow milk has less amount of α-la, lactoferrin, immunoglobulins and lysozyme as seen in previous Table 3.

Buffalo Milk

Buffalo (Bubalus bubalis) milk production is stated the second largest source after bovine milk in the world. Total universal milk production is around 13% (87.5million tones/year), and also has high annual growth rates. It has high ratios of fat, protein, lactose, total solids and some minerals compared to cow, human, goat and camel milk [41].

One of the most countries that produces buffalo milk is Pakistan with 35.5 billion liters annual milk production (67.04%) followed by cow (31.56%) milk [42,43].

Buffalo milk has all useful compounds, like peptides, fatty acids, vitamins, and other bioactive compounds. It characterized with elevated concentrations of total protein, medium chain fatty acids, CLA, vitamins A, D, C, B_6, minerals (calcium, magnesium, phosphorus, potassium, zinc and iron) and contents of retinol and tocopherols than cow milk. Buffalo milk contains high ratios of immunoglobulins (Ig) which identified of (IgGa, IgA_1, IgA_2 and IgM) against cow and breast milk. Cow milk has lower content of lactoferrin than in buffalo milk, as displayed in Table 5 which compared both to human milk [44,45].

Protein Fractions	Buffalo Milk	Cow Milk	Human Milk
Total Casein (CN)	32-40	24.6-28	2.4-4.2
α-S1 CN	8.9	8-10.7	0.77
α-S2 CN	5.1	2.8-3.4	-
β-CN	12.6-20.9	8.6-9.3	3.87
K-CN	4.1-5.4	2.3-3.3	0.14
Γ-CN	-	0.8	-
β-lg	3.9	3.2-3.3	-
α-la	1.4	1.2-1.3	1.9-3.4
Serum albumin	0.29	0.3-0.4	0.4-0.5
Lactoferrin	0.03-3.4	0.02-0.5	1.5-2.0
Lysozyme	120-152×10-6	70-600×10-6	0.1-0.89
Immunoglobulins (Ig)	10.66	0.5-1.0	0.96-1.3

Table 5: Differentiation between protein fractions (g/l) of buffalo, cow and human milk.

Buffalo milk protein has ~80% caseins and ~20% whey proteins with traces of minor proteins, so BM is more preferred to consumer [46]. It possesses more colloidal calcium and phosphorus accompanied with high ratio of calcium than cow one. Contrast cow milk which contained 90-95% of casein micelles; BM owns the casein in the micelles form. In addition, buffalo milk contains slightly higher ratios of β-lactoglobulin than cow milk, which is absent in human milk [41].

Also, same Table appeared that buffalo milk (BM) had higher content of α-s2-CN and κ-casein. The excessive amounts of κ-CN in BM can be believed that it acts as a laborer to accelerate the enzymatic phase of rennet coagulation and therefore it will be needed little quantity of chymosin in cheese manufacture [44].

There was great homology (97.2%) between αs1-CN of BM which contains a single 199 residue polypeptide chain compared to variant B of αs1-CN of bovine milk. Buffalo αs2-CN is considered of a single polypeptide chain with 207 residues in length and has very high homology (97.9%) compared with cow αs2-CN. Table 6 gave an outline of amino acid substitutions in both of buffalo and cow milk [47].

Amino Acid Sequences													
αs1-CN	4	4	42	74	115	119	148	174	192				
Buffalo	Gln	Gln	Thr	Ile	Leu	Gln	Gln	Pro	Gly				
Cow	His	His	Lys	Asn	Ser	Arg	Glu	Thr	Glu				
αs2-CN	2	2	44	147	157	170	175	176	182	199			
Buffalo	His	His	Ile	Ile	Asp	His	Thr	Try	Try	Asn			
Cow	Asn	Asn	Val	Phe	Glu	Arg	Ala	Leu	His	Lys			
β- CN	25	25	57	84	108	164							
Buffalo	His	His	Met	Lys	Ile	Pro							
Cow	Arg	Arg	Thr	Asn	Val	His							
κ-CN	14	14	80	96	126	128	138	140	147	149	156	162	168
Buffalo	Glu	Glu	Pro	Thr	Val	Val	Ile	Asn	Ala	Ser	Val	Ala	Val
Cow	Asp	Asp	Ser	Ala	Ala	Gly	Val	Ser	Asp	Pro	Pro	Val	Ala
β-lg	1	1											
Buffalo	Ile	Ile											
Cow	Leu	Leu											
α-la	17												
Buffalo	Asp												
Cow	Gly												

Table 6: Amino acids sequences of buffalo and cow milk protein fractions.

Goat Milk

As mentioned in a number of researches, about 500 breeds of goats live in the high mountains and deserts in the world which found more 95% of its population in developing countries [48]. India is the largest producers of goat milk in the world (26.3%) followed by Bangladesh (14.3%), and leaders among the European countries are France (3.8%) and Greece (3.3%). According to the rapid population growth, production of goat milk becomes a substantial issue to human nutrition in the tropical developing countries [49,50]. United Nations explained that goat milk can be used as an important application to attain the 2030 Agenda for sustainable development goals [51]. Sharma, et al. [52] exhibited goat milk proteins which are composed of 80% casein the major protein and 20% whey protein; have remarkable variations in their compositions against milk of other mammalian species. They are a family of acidic, proline-rich phospho-proteins designed to form spherical, large, micelles structures in colloidal suspension with calcium phosphate. Moreover, the obvious differences between cow's milk and goat's milk in digestion is that the latter has a shorter clotting time, lower resistance to heat, weaker curd hardness and lower cheese yield what has been explained by the "homogeneity" of goat's milk fat [53]. Feeding on goat milk; which contains about 1.2g calcium and 1 g phosphate/L furnishes a worthy ratio of them similar to those in cow milk. The soft curd and high buffering capacity of goat milk may be perfect for adult humans suffering from gastrointestinal disturbances and ulcers [50].

An important nutritional property of goat's milk for infants, adults, or those with a cow's milk allergy is that it has a high biological value digestive and physiological capacity [54]. Due to lower content of αs1-casein (5% of the total casein) in goat milk that makes it less susceptible to cause allergic reaction compared to cow milk and therefore decreases the sensitivity to the other allergen protein, which is β-lactoglobulin. As well, data declared that the best composition of exogenous amino acids can be found in goat and sheep milk. In general, goat milk compared to cow milk is less rich in lactose, fat and proteins, but has similar mineral content [49].

GM which its density ranges between 1.026 and 1.042; gained alkaline pH 6.3 to 6.7 verses to cow milk which is tend to acidity. It has a white-matte color, no β-carotene and a sweet and pleasant distinctive "freshly milked taste"; however, it can sometimes, at the end of lactation or after a period of storage in a cold environment, acquire a certain flavor one can describe as "animalic" [54]. The intense of goat milk flavor may be cause of the release of short-chain fatty acids during the handling of milk [50].

One of the key benefits of utilizing goats for milk production is their ability to thrive in challenging environmental conditions compared to cows. This makes goats a practical choice for milk production, especially during times of climate change that can negatively impact livestock. The unique qualities of goats make them a preferred option for milk production, particularly for vulnerable populations and those with financial constraints. The growing global acceptance of goat milk for human consumption is evident in the rapidly expanding goat milk market worldwide. Therefore, promoting research on goat milk production is crucial for enhancing food security and combating hunger on a global scale. Despite the lack of existing research on the importance of goat milk in enhancing food security, it is clear that further scholarly research on this topic is essential [55].

Goat milk has a higher concentration of non-protein nitrogen compounds compared to sheep and cow milk. Additionally, it contains fewer types of casein proteins. This unique composition results in a softer texture in goat milk yogurt, as opposed to sheep milk which has a stronger ability to coagulate. The differences in casein proteins in sheep milk are the primary reasons for its quicker curd formation and firmer rennet coagulation. Both goat and sheep milk also boast higher levels of essential minerals and vitamins compared to cow milk [54].

Sheep Milk

Sheep milk production is prominent in Asia, Africa, and Europe, with a global output of 10.61 million tons. China, Turkey, and Greece are among the top producers of sheep milk. The Mediterranean region is a key area for sheep milk production, where important dairy sheep breeds like Awassi, East Friesian, and Lacunae are commonly found [56]. However, family-scale farms are a major part of the goat and sheep milk production. Sheep milk is higher in total solids, fat, protein and caseins and also has larger amount of minerals and vitamins. Sheep milk, in addition shows more marked white opacity and has a special odor originally called “suarda” or “sheepy”. This feature is relatively less evident in milk that is stored in good hygienic condition [54].

Sheep milk (SM) is characterized by a high percentage of whey proteins 1.02g/100g and similar to buffalo milk in casein content 4.18g/100g [57]. Additionally, SM when compared to cow milk; it comprises higher ratios of macro-nutritional fractions; like protein, fat and total solid. Recently, it was detected that sheep milk has higher ratios of both essential and trace minerals such as of Ca, P, Mg, Zn, Mn, Cu, and Na compared to cow milk. Consequently, the consumption of SM may support bone health compared to cow one [58].

Furthermore, Pandya, et al. [59] illustrated that sheep milk contains a variety of beneficial components such as peptides, oligosaccharides, fucosylated oligosaccharides, hormones, growth factors, mucin, gangliosides, and endogenous peptides, lipids, vitamins and minerals. These elements are naturally present in milk upon secretion and serve to enhance health in a way that complements synthetic pharmaceutical drugs rather than replacing them. Sheep milk is considered a natural functional milk due to its exceptional nutritional content, easy digestibility, and therapeutic and dietary properties.

Sheep and goat casein micelles have higher mineralization levels, and they are less hydrated, solvated, and heat stable than bovine casein micelles [54]. Moreover, the molecular form and amino acid sequence of the milk proteins may differ from one species to another (e.g. at neutral pH β-lg is present as monomer in horse milk, but as dimer in ruminant milk; which additionally affects the protein digestibility, nutritional quality and thermo-stability [60]. Sheep milk differs from goat one in the casein fractions ratios. α-S1 CN content is higher in sheep milk than in goat milk which contains more content of κ-casein. The concentration of protein fractions for both sheep and goat milk were displayed in Table 7 [44]. A comparative evaluation of amino acids in sheep milk compared to goat, cow and buffalo milk declared in Table 8 [61].

Protein fractions	Sheep milk	Goat milk
Total Casein (CN)	41.8-46	23.3-46.3
α-S1 CN	15.4-22.1	0.0-13.0
α-S2 CN	-	2.3-11.6
β-CN	15.6-17.6	0.0-29.6
K-CN	3.2-4.3	2.8-13.4
β-lg	6.5-8.5	1.5-5.0
α-la	1.0-1.9	0.7-2.3

Table 7: Some Protein fractions (g/l) of sheep and goat milk.

Amino Acids (g/100g)	Cow Milk	Goat Milk	Buffalo Milk	Sheep Milk
Aspartic acid	7.8	7.4	7.13	6.5
Threonine	4.5	5.7	5.714	4.4
Serine	4.8	5.2	4.65	3.4
Glutamic acid	23.2	19.3	21.4	14.5
Proline	9.6	14.6	12	16.2
Cystine	0.6	0.6	0.586	0.9
Glycine	1.8	2.1	1.93	3.5
Alanine	3	3.6	3.03	2.4
Valine	4.8	5.7	6.76	6.4
Methionine	1.8	3.5	0.928	2.7
Isoleucine	4.2	7.1	5.714	4.6
Leucine	8.7	8.2	9.792	9.9
Tyrosine	4.5	4.8	3.858	3.8
Phenylalanine	4.8	6	4.713	4.3
Histidine	3	5	2.73	6.7
Lysine	8.1	8.2	7.497	7.8

Table 8: Amino acid profile of cow, goat, sheep and buffalo milk.

She-Camel Milk

Camel is an animal can be used for multi-purposes with high productions. In deserts camel can live and faces the problems like raise of global warming and scarcity of food and water. In 2018, the estimated global population was roughly 30 million, with the majority residing in Africa. Specifically, around 80% of the population calls Africa home, with 60% of that number concentrated in the Horn of Africa, notably in Somalia [62]. Four North East African countries Somalia, Sudan, Kenya and Ethiopia own about 60% of the dromedary camel population. Somalia has the largest herd in the world with over 6 million heads. Daily yields between 3 to 10 kg in a lactation period of 12 to 18 months are common [63]. Camel milk is drunk throughout Arabia, and it has low fat and high nutritious value. Lately, the European Union has also allowed import of camel milk from African and Asian countries into the EU [64].

Fresh camel milk has an ordinary odor, opaque white color, smooth texture due to homogenized milk fat and salty taste because camel is fond of grazing on salty vegetation. The chemical composition of camel milk compared to cow one is cleared in Table 9. Camel as cow milk has highly obvious protein compared to human milk but lower than buffalo milk. It has a similar low-fat content as human than buffalo and cow milk. Camel milk is similar to goat milk in protein and lactose contents. It has a comparable content of fat, moisture, total solids and carbohydrate with cow and goat milk. So, the composition of camel milk is closer to human milk and of high nutritional value and therapeutic effects [64,65].

Parameters	Camel milk	Cow milk
Water %	90	85
Total Solids %	10	13
Fat %	2	4
Insulin (µu/ml)	40.5	16.3
β-lg mg/ml	0	3500
α-la mg/ml	3500	1200
K-casein %	5	14
Whey protein %	1	0.8
Omega-6 %	3.5	5.2

Table 9: Comparison between camel and cow milk in some parameters.

Lactose concentration is about 4.8%, but this sugar is easily metabolized by persons suffering from lactose intolerance. Camel milk also is suitable for allergic patients with absence of β-lg high amount of α-la and a different beta-casein. Camel milk is considered harmonious with human one due to it consists of a number of Igs. Camel milk dose not has β-LG makes it similar to human milk, so it is able to substitute human milk for infant diet formulation compared to cow milk. High level of whey proteins fractions in camel milk might supply great advantages of functional properties to camel milk consumers [66].

On the hand, this milk includes high ratios of Fe, Cu and chloride which make its salty taste. One of the most important features is long-shelf life; 3 days for raw milk, 10 days for pasteurized one. This property is naturally coming from its antibacterial system (lysozyme, lactoferrin and hydrogen peroxide) [67].

Even though camel whey proteins have higher heat stability than bovine whey proteins at temperatures between 63 and 90°C, bovine milk coagulates much slower at higher temperatures. This could be related to the absence or very low levels of β-lg and k-casein in camel milk as milk is more resistant to heat when it is characterized by a molar β-lg to k-casein ratio close to 1 [44].

Equine (Mare) Milk

The global horse population exceeds 60 million, with a majority found in America and Asia. In Europe, horses are primarily concentrated in the eastern regions. In impoverished and developing nations, horses are commonly used as a means of transportation, whereas in developed countries they serve various purposes, including milk production, especially in Europe. Compared to cow milk, horse milk has lower levels of total solids, fat, and protein, but higher levels of lactose, making their composition more similar to that of human milk [68,69]. Mongolia, Kazakhstan, Kyrgyzstan or Tajikistan; these four countries are known of consuming mare's milk [70]. Although that the exact production amount of mare's milk is not accurately known, there are about 30 million people all over the world are regularly consuming this type of milk. As well in Italy, Hungary, The Netherlands and Germany; it has gained more value due to its positive health impacts; almost 1 million kg of mare's milk are produced in Europe [71].

So, mare's milk casein is in a moderate level between human and bovine milk. The ratio of casein to whey proteins in horse is around 1.1:1, which more closely likes human milk [70]. Compared to cow milk; the stingy existence of k-casein in mare milk is causing higher average size of the micelle and showing various mechanisms for micelle stability [72]; these factors with the low total casein content, are maybe caused the weak coagulation properties. Table 10 had illustrated a comparison between equine, bovine and human milk either colostrum or mature milk [73].

Items	Equine	Bovine	Human
Colostrum			
Protein, g kg^{-1}	128.9 (63–191)	99.6 (33–135.8)	20.0 (12–36)
Immunoglobulins, g kg^{-1}	79.2 (49–107)	52.3 (31–87)	18.79
Fat, g kg^{-1}	14.5 (6.9–29	46.3 (36–65)	34.3 (28–38)
Lactose, g kg^{-1}	39.5 (33–46)	34.7 (25–48)	63.0 (51–70)
Milk			
Gross energy, kJ kg^{-1}	2008	2820	2832.5
Protein, g kg^{-1}	21.5 (15–28)	32.5 (31–38)	15.2 (9–21.4)
NPN × 6.38, %	11.21	5.23	20.42
Casein, %	50	77.23	26.06
Whey protein, %	38.79	17.54	53.52
Casein: Whey Protein	1.1:1	4.7:1	0.4:1
b-Lactoglobulin, %	30.75	20.1	Absent
α-Lactalbumin, %	28.55	53.59	42.37
Immunoglobulins, %	19.77	11.73	18.15
Serum albumin, %	4.45	6.2	7.56
Lysozyme, %	6.59	Trace	1.66
Lactoferrin, %	9.89	8.38	30.26
Fat, g kg^{-1}	12.1 (5–20)	36.1 (35–9)	36.4 (35–40)
Lactose, g kg^{-1}	63.7 (58–70)	48.8 (44–49)	67 (63–70)
Ash, g kg^{-1}	4.2 (3–5)	7.8 (7–8)	2.2 (2–3)

Table 10: Comparison between equine, bovine, and human colostrum, and mature milk.

In the same line, Mare milk has major biological value than bovine milk. Content of threonine, valine, cystine, tyrosine, and lysine amino acids decreased, but both of glutamic acid and proline raised with time after delivery. There are little reports about equine milk protein variation, especially for the balance between casein and whey protein which considered the main cause of cow milk allergy [74,75]. Affirmative impact of mare milk consumption on diseases like atopic dermatitis had been displayed. Many studies recommended mare milk as a suitable substitute for cow milk in cases of severe IgE-mediated cow milk allergy [76].

Although horse milk contains a high percentage of calcium compared to cow's milk, horse milk is weak in the acid and enzymatic coagulation process. Many studies mentioned that horse casein doesn't coagulate by *calf chymosin* at pH 6.6 or by various enzymes but some micellar flocculation not gel formation [69]. One study used *Withania coagulans* extracted from fruit had coagulated milk, but they did not report any details of the physical and chemical properties of the curd obtained [77].

Donkey (Jenny) Milk

Eight million heads which considered being the highest donkey population all over the world are in China; also, major populations are in Pakistan and Ethiopia. In the EU, there are around 288,000 donkeys, most of which live in Spain, France, Romania, and Italy. Jenny milk has been processed to meet nutritional requirements of definite people; this has improved income from donkey enterprises [62,78].

Owing to its similarity to human milk, jenny milk is given an increasing attention, especially in Europe. Jenny milk has low contents of fat and cholesterol, even so it is considered most identical to human milk in protein and lactose contents. Human milk includes lower protein content compared to cow, buffalo, yak, camel, goat, sheep, and reindeer milk. Jenny milk, if modified appropriately, could be used as an alternative substitute in infant formulas to evade cow milk allergies [75,79].

Inadequate information accrued about chemistry and nutritional properties of jenny milk contrast to mare milk. Obtainable results stated that jenny milk is nearly like mare milk with low total solids (8-10%) and protein (1.5-1.8%) and high lactose (6-7%) and fat varies within 0.28-1.82%. Likewise, its protein is low in casein (47.3%) and whey protein (36.9%), but it is rationally high in lactose and β-lactoglobulin (30%). The casein/ total protein ratio is once more similar to breast milk. It has Immunoglobulins (IgGs) in high content compared with human and bovine milk [75,80].

Jenny milk owns high level in valine and lysine comparing cow, buffalo, goat, ewe, camel, and mare milk. It also included greater serine (6.2% vs. 4.8% and 5.1%), glutamic acid (22.8% vs. 23% and 17.8%), arginine (4.6% vs. 3.3% and 4%), and valine (6.5% vs. 4.8% and 6%) and lower cystine (0.4% vs. 0.6% and 1.7%) than cow and human milks, respectively. Its protein mostly contains αS1- and β-caseins, lysozyme, α-lactalbumin, β-lactoglobulin. β-lactoglobulin and α-lactalbumin contents were in average of 3.75 and 1.8 mg/ml, respectively. Overall, jenny milk is characterized by low casein and high lysozyme content (1.0 mg/ml), compared with other milk [78,81].

Although the characteristics of donkey milk are similar to those of breast milk, the expansion of its production on a commercial scale is uncertain. With all these special properties of donkey milk and some economic possibilities it can support children's food [81].

Yak Milk

Yak milk is predominantly produced in the Qinghai-Tibet region of China, where yaks thrive in the challenging cold and high-altitude environments. China boasts a yak population of approximately 13 million, representing over 90% of the global yak population. The global production volume of yak milk is not officially documented, with estimates varying significantly from 0.7 to 40 million tons, as noted by Zhang, et al, [82]. Compared to cow milk, yak milk contains higher levels of dry matter, fat, and protein. The casein profile is similar, with slight variations in the concentrations of β and κ fractions. Notably, the casein micelle in yak milk is more hydrated and contains more colloidal calcium phosphate. While the average size of the micelle and fat globules in yak milk is slightly larger than in cow milk, as highlighted by Faccia, et al. [69].

The unique composition of yak milk lends itself to easy coagulation using rennet, a characteristic not commonly found in other types of milk. Bovine chymosin can effectively hydrolyze k-casein in yak milk, although the gel formation process is slower compared to cow milk. The firmer gel structure of yak milk is attributed to its elevated levels of colloidal calcium phosphate, facilitating the linking of casein micelles in multiple directions. Additionally, the larger size and higher hydration of yak micelles contribute to reduced curd syneresis and enhanced moisture retention. Yak milk's coagulation properties are particularly advantageous for producing hard cheese in comparison to Holstein milk, owing to its higher concentrations of casein and calcium. By incorporating lactic acid bacteria starter, rennet, and $CaCl_2$, high-quality hard cheese can be successfully crafted from yak milk, as detailed in the study by Faccia, et al. [69].

Digestibility of Different Milk Protein Species

The collapse of proteins initiates in the stomach with the assistance of pepsins, then by further digestion in the intestines facilitated by enzymes such as trypsin, chymotrypsin, and various peptidases. In some cases, newborns may possess a chymosin-like enzyme alongside pepsin in their gastric fluid, although this enzyme typically diminishes around the eleventh day post-birth. Both chymosin and pepsin belong to the group of aspartic proteinases that utilize aspartic acid residues in their active center.

These enzymes exhibit a preference for breaking down the Phe105–Met106 bond in κ-casein, with pepsin also displaying non-specific proteolytic activity towards bonds containing Trp, Tyr, Leu, or Val residues. Consequently, pepsin depict higher proteolytic activity compared to its milk clotting activity in contrast to chymosin. The mechanism of action for both chymosin and pepsin is anticipated to be similar in clotting milk, as they both target the same site [5].

The stability and effectiveness of chymosin and pepsin are influenced by pH levels. Chymosin is most stable within a pH range of 5.3–6.3 but loses effectiveness under acidic conditions below pH 3–4 and at high alkaline pH levels above 9.8. In contrast, pepsin exhibits the highest proteolytic activity at a pH of 2, with an optimal range of 2–5, remaining active within a pH range of 5.5–7.5 and becoming irreversibly deactivated at pH levels above 7.5.

The breakdown of milk proteins in humans and the transportation of peptides or intact proteins into the bloodstream are not fully understood. Research indicates that whey proteins tend to reach the upper jejunum more rapidly than caseins, suggesting that whey proteins are more easily released into the duodenum compared to caseins, which form a clot in the acidic stomach environment. This leads to caseins being classified as "slow" digested proteins and whey proteins as "fast" digested proteins [5,35,83].

The study by Ye, et al. [84] elucidates that pepsin exhibits specificity in targeting different sites for protein breakdown compared to intestinal proteases such as trypsin and chymotrypsin. Specifically, pepsin shows a preference for acting on κ-casein within casein micelles, leading to the coagulation of the casein component of milk proteins in acidic conditions. This action results in the separation of the casein fraction from the soluble whey protein fraction, underscoring the crucial role of the stomach in initiating protein digestion.

The composition of casein in the type of milk consumed, as well as the ratio between casein and whey proteins, plays a significant role in determining the rate of protein digestion in the stomach. Cow's milk, characterized by high casein content, forms a dense coagulum that slows down protein breakdown and promotes absorption. On the other hand, milk from mares, jennies, camels, and goats forms softer curds in the stomach, facilitating easier digestion [44].

Additionally, mother's milk creates soft and fragile protein aggregates in the infant's stomach [85]. Research indicates that the rates of tryptic hydrolysis for micellar caseins from cattle, human, goat, and horse milk are approximately 76–90%, 100%, 96%, and 92%, respectively. The higher susceptibility of human and goat milk to hydrolysis is attributed to their smaller micellar aggregates and elevated levels of β-casein in their micellar structures, in contrast to cattle milk, which contains higher levels of αs1-casein [5].

Also, variations in protein composition, casein micelle structure, processing temperature, and time can indeed influence the structure of curd in the stomach. These factors play a crucial role in determining the rate at which proteins are released to the small intestine and their absorption efficiency, as highlighted in the study by Roy, et al. [5]. It is important to consider these variables when evaluating the impact of dairy products on digestion and nutrient absorption in order to optimize nutritional outcomes.

The digestibility of different protein fractions varies significantly across various milk sources. For instance, β-lg in mare milk is more easily digested compared to goat β-lg, while β-lg in goat and sheep milk is easier to digest than bovine β-lg.

Conversely, α-lactalbumin from all species is known to be more challenging to digest. Whey protein fractions like lactoferrin and serum albumin found in breast and mare milk are easily digested, similar to bovine and goat milk, as noted in the study by Inglingstad, et al. [35]. Milk proteins play a critical role not only in nutrition but also in various biological functions.

The bioactive peptides released during milk protein digestion are considered a promising alternative, along with the released amino acids. However, the complete understanding of how milk proteins are metabolized in the human body and how different peptides are utilized remains a topic that is not fully elucidated, as highlighted by Inglingstad, et al. [35] Figure 3.

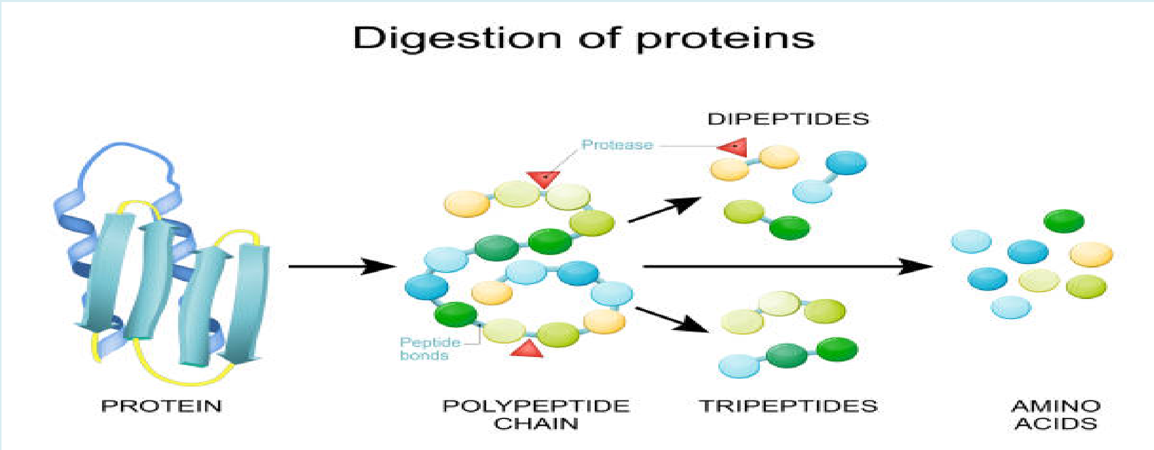

Figure 3: Enzymatic Digestion process of milk proteins.

Different Milk species in Some Dairy products

The variation in the composition of milk protein species makes their applicability in the industry different as well. In this section, it will be presented the most important dairy products in which the common species are interfered and the extent to which other species can be applied.

Fermented Dairy Products

The development of fermented dairy products using a combination of milk species, such as goat and camel with cow milk, has led to improved quality and the introduction of new products to the market. Yogurt, as noted by Aryana, et al. [86], is a widely consumed fermented dairy product globally, with annual production increasing significantly over the years. In 2015, yogurt production reached £4742.1 million, a substantial increase from £982.6 million in 1990. Despite the biological benefits and similarities to breast milk, donkey milk remains relatively underutilized in the dairy market. However, a study by Chivari, et al. [87] successfully demonstrated the production of a fermented beverage using donkey milk and probiotic bacteria like *Lactobacillus rhamnosus* and *Lactobacillus casei*. This study showcased the potential of incorporating jenny milk into fermented beverages enriched with probiotics, featuring a high lysozyme content and appealing taste profile.

Furthermore, research by Wang, et al. [88] highlighted that donkey milk possesses lower allergenic properties compared to cow milk and is rich in essential amino acids and polyunsaturated fatty acids (PUFAs) such as a-linolenic acid and linoleic acid. These findings underscore the nutritional value and potential health benefits of donkey milk as a viable alternative in the dairy industry.

The research findings suggest that utilizing sheep's milk to create set yogurt with varying fat concentrations can yield superior quality and enhanced flavor. Specifically, sheep yogurt with low fat content, derived from 6.6% milk fat, demonstrated improved quality and reduced syneresis compared to yogurt with higher fat content. Furthermore, as the fat ratio decreased, the firmness of the curd also decreased, as indicated by Kaminarides, et al. [89]. This information underscores the potential benefits of producing sheep yogurt with lower fat content for optimal quality and texture.

The research study on yogurt production using sheep, camel, and goat milk highlighted the unique characteristics of camel milk that necessitate a longer incubation time of 16-18 hours compared to the 3-4 hours required for sheep and goat milk. This extended coagulation time in camel milk can be attributed to several factors, including the larger size of casein micelles, which results in a less efficient aggregation process and weaker gel formation, leading to a softer coagulum. Additionally, the antibacterial properties present in camel milk may interfere with the activity of lactic acid bacteria crucial for fermentation. Furthermore, camel milk exhibits lower levels of K-casein and total solids in comparison to sheep and goat milk [90]. In a similar study by Galeboea, et al. [91], it was found that when camel yogurt was enhanced with calcium chloride, gelatin, and skim milk powder, it exhibited comparable chemical and microbiological characteristics to cow yogurt. However, cow yogurt was preferred in terms of sensory properties. The addition of exopolysaccharides was also noted to improve yogurt texture more effectively than other additives [92].

The study made by Khalifa, et al. [93] on the production of set yogurt using various milk sources, including buffalo, camel, goat, and their combinations in different ratios, yielded significant findings. Camel milk was observed to contribute to a more liquid-like structure, while goat milk resulted in a mildly firm texture in comparison to the firm curd produced by buffalo milk. Blending buffalo milk with camel and goat milk in ratios of 50:50, 60:40, and 90:10 was found to enhance the characteristics of the curd, prolong its shelf life, and boost consumer acceptance. This research highlights the potential benefits of utilizing different milk sources and their combinations in yogurt production to improve product quality and consumer satisfaction.

The incorporation of mixed goat and cow milk in yogurt production has been shown to offer various benefits. Studies by Temerbayeva, et al. [94] demonstrated that blending goat and cow milk resulted in a yogurt product with higher levels of vitamins and protein, while reducing fat content. Additionally, the sensory attributes of the yogurt improved when combining goat and cow milk compared to using goat milk alone, with a ratio of 70% goat milk and 30% cow milk. Similarly, research conducted by Trentin, et al. [95] on yogurt produced from sheep and bovine milk, as well as their combinations, revealed that sheep milk contributed to a better nutritional profile in the final product. These findings suggest that incorporating different milk sources in yogurt production can enhance nutritional value and sensory qualities, highlighting the potential for innovation in dairy product development.

Kumis, a traditional drink made from mare's milk, is renowned in various Asian countries for its perceived medicinal properties. It is believed to offer benefits to the nervous and immune systems, as well as aid in the treatment of conditions affecting the cardiovascular, respiratory, gastrointestinal, and urinary systems. This is attributed to its rich composition of enzymes, trace elements, antibiotics, and a diverse array of vitamins such as A, B_1, B_2, B_{12}, D, E, and C. Research suggests that kumis can be beneficial for individuals recovering from certain illnesses and for pregnant women, as recommended by Jastrzebska, et al. [96]. It is important to consider these potential health benefits when incorporating kumis into dietary practices.

Cheese Product

The utilization of camel milk for cheese-making present's challenges due to lower cheese yield and inferior product quality compared to traditional dairy sources. However, various efforts have been made to overcome these obstacles and produce different types of camel milk cheeses. One strategy involves using camel gastric enzymes instead of chymosin for cheese processing. Research studies have indicated that camel-derived chymosin exhibits superior clotting activity and κ-casein cleavage potential in comparison to chymosin sourced from other animals [97,98]. This highlights the potential for utilizing camel gastric enzymes to enhance the cheese-making process and improve the quality of camel milk cheeses.

The research conducted by Khan, et al. [99] highlights the successful creation of soft white cheese from camel's milk through a modified approach. By lowering the pH to 5.5 using citric acid or starter cultures and incorporating calcium chloride before rennet, they were able to produce cheese from camel milk. Despite a lower yield compared to cow or buffalo milk, the cheese made with starter cultures was preferred over acidification. This suggests that traditional cheese-making methods may not be optimal for camel milk and that alternative techniques are necessary for successful incorporation of camel milk into cheese production.

The study by Konuspayeva, et al. [100] highlights key factors influencing the use of camel milk in cheese production. The lactation period significantly impacts curd formation, with initial 12 days post-delivery showing no curd formation, followed by a soft coagulation phase starting after 24 days, suitable for cheese production. Optimal coagulation temperature was identified at 36°C with a lower pH of 5.78, contrasting with 20°C and a higher pH of 6.26. The introduction of a new coagulant, "Chy-Max M," derived from Hansen™ (Denmark) containing camel chymosine, demonstrated effectiveness in cheese production. Various additives have been explored to enhance the quantity and quality of camel milk cheese. For example, the addition of calcium chloride during cheese manufacturing has shown to reduce coagulation time, improve cheese yield, and maintain organoleptic quality. Substituting camel rennet for bovine rennet has shown enhanced coagulation effects and reduced coagulation time, potentially due to the presence of pepsin enzyme in the rennet preparation. Incorporating yogurt culture or other lactic acid bacteria (LAB) with rennet in camel milk has accelerated coagulation by increasing lactic acid content, leading to improved texture and firmness of the curd. However, the addition of LAB or yogurt culture alone without rennet did not yield significant improvements in coagulation efficiency, as noted by Arain, et al. [98].

The challenges in cheese production from jenny milk, similar to camel milk, are attributed to its high whey protein and lysozyme content. A study by Iannella [101] utilized pure camel chymosin and starter cultures to create donkey cheese, yielding lower results compared to cow cheese, but with potential for improvement in the future. Goat cheese is widely produced globally, particularly in Mediterranean regions such as Turkey, Greece, Syria, and Iran. Initially focused on soft cheese, the production has evolved to include hard and ripened varieties. Factors influencing the sensory properties of goat milk-based products include genetic heredity of the animal, environmental conditions, and processing technologies [54]. Table 11 provides an overview of the potential applications of various milk species in different dairy products, highlighting the diversity and possibilities within the dairy industry.

Milk Species	Fermented Product	Cheese Product
Cow	Very common	Very common
Buffalo	Very common	Common
Goat	Slightly firm	Common
Sheep	Firm	Common
Camel	Liquid (need some modification)	Can produce
Mare	Common (Kumis)	Need Some Modification
Donkey	Can used	Can produce (need some modification)

Table 11: Summary of the possibilities of various milk species in some dairy products.

The study conducted by Saadi, et al. [102] focused on the production of soft cheese using camel milk and aimed to address production challenges. They experimented with soft cheese formulations using camel milk, sheep milk, and various combinations of both. The data analysis indicated significant variations in total solids, fat, and protein content among camel soft cheese, sheep soft cheese, and their blends.

Notably, camel cheese exhibited the highest total solids content, while the cheese produced from a 50:50 ratio of the two milk types showed the lowest concentration. It was observed that camel milk experienced a notable loss of proteins, leading to reduced total solids content during storage. In contrast, sheep milk demonstrated an increase in total solids and cheese yield over the storage period. These findings underscore the importance of understanding the compositional differences between camel and sheep milk in soft cheese production and highlight the potential impact on product quality and stability during storage. Further research and optimization of processing techniques may be necessary to address protein loss issues associated with camel milk and enhance the overall quality of soft cheese formulations.

Conclusion

Milk is indeed a valuable source of nutrients essential for human growth and development, provided by nature for various species. Each species' milk is uniquely tailored to meet the specific needs of its offspring. In the past, certain milk species were underutilized due to limited production and a lack of awareness regarding their distinct properties. However, there is a growing trend in the dairy industry to explore and capitalize on the benefits of these lesser-known milk species. As a result, an increasing number of food and dairy products are being manufactured using non-traditional milk sources, with the aim of introducing these products to a wider audience globally. This shift towards utilizing a variety of milk species in the production of dairy products reflects a recognition of the diverse nutritional benefits and unique properties that each type of milk can offer.

Future Perspectives and Recommendations

- It is essential to prioritize research and awareness initiatives focused on the benefits of breastfeeding and increasing maternal understanding of its importance based on scientific evidence.
- Additionally, further comprehensive research is needed to improve the nutritional and sensory qualities of camel milk products to compete with those derived from other livestock.
- Moreover, the development of innovative technologies and refining processing techniques are critical for diversifying camel milk into various dairy products, including low-fat milk, skim milk, and flavored options tailored for specific dietary or medical needs.
- Increasing consumer awareness of the advantages of alternative milks such as camel, horse, and donkey milk is key to fostering acceptance and consumption. It is imperative to conduct scientific studies to address challenges associated with incorporating these unfamiliar milks into dairy products that align with consumer preferences and demands.

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