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Review

Nutraceutical and Functional Properties of Camelids' Milk

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Abstract: In most areas of the world, camelids are considered exotic animals, living only in zoological gardens. Additionally, considering the original lands where they were previously bred with specific economic and social aims, today it is possible to detect a reduction in their total numbers. Typically bred as working animals for goods transportation in desert regions, and as a source of meat and milk, in recent years, camels have been dismissed due to the construction of new roads for motor vehicles, the migration of nomadic populations from deserts to urban zones, and the choice of some autochthonous bovine breeds as sources of meat and milk. The decline in camelids heads seems irreversible. Camels should be considered a valid source of food in marginal areas; the peculiar quality parameters of their milk, showing the proper characteristics for the use of this milk in human nutrition, can justify the choice for breeding them, rather than considering camels only as objects of amusement.

Keywords: camel milk; dromedary milk; nutraceutical foods; immunogenicity; functional foods

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1. Introduction

Human milk represents the best food for newborn children, considering its nutritional and immunological properties, and for these reasons, can be considered very safe for infant nutrition [1]. After the infant weaning or early termination of breastfeeding, normally cow milk represents the most common food for infant nutrition but unfortunately can also represent the first allergen in life [2]. In fact, in several countries, cow milk, a member of the "Big Eight" food allergens, together with egg, soy, wheat, peanuts, tree nuts, fish, and shellfish, is the most important food allergen in babies and children [3].

Camel milk has always represented an important food for nomadic people in the arid parts of the world; recently, camel milk attracted great attention as a possible replacer to dairy cow's milk because of its therapeutic effects [4]. The use of alternative milk for feeding children can be effective in reducing the development of gastrointestinal disorders [5]. Initially, goat milk has been investigated [6]; later, in the 1990s, donkey milk started to stir great interest in clinical trials [7,8]. Recently, the use of camel milk to replace dairy cows and other kinds of milk (goat, donkey, and mare) has attracted interest in the scientific community [9]. Allergic symptoms to cow's milk proteins can be treated with camel's milk immunoglobulins (Igs) [10]. The antiallergenic properties of camel milk are also due to having a similar protein profile to human mother's milk, with the absence of β-lactoglobulin and a high content of α-lactalbumin [11]. Additionally, considering the high content of antioxidant and antimicrobial molecules in camel's milk, it is possible to detect a crucial role of this milk in many health bodies functions. In fact, camel milk is characterized by an insulin content (42 μU/mL) that is not degraded in the forestomach and bypass to intestines, leading to a reduction in blood glucose levels; therefore, it is effective in diabetes treatment [12]. Camel milk also shows antibacterial and antiviral activities due to having bioactive peptides able to perform important physiological properties, enhancing the immune system defense [13]. For this reason, camel milk is used as a remedy for diarrhea caused by viruses (*Rotavirus*), and for both B and C hepatitis [14]. Camel milk can be considered a highly suitable vehicle in delivering probiotics and can be useful in maintaining gut health [15]. In the next sections of this review article, the functional and nutraceutical properties of camelids milk will be described, showing several interesting uses of this food in human nutrition for different treatments of the most common diseases.

2. Dromedary and Bactrian Camel Milk

Milk is considered a complete food, very important in the human diet both for children and adults [16]. Milk consumption is estimated at around 85 kg/year/per capita, even if there are large differences among different areas: In developed regions, it is estimated at around 214 kg/year/per capita, while in developing regions, it is around 55 kg/year/per capita [17]. Specifically, in East and Southeast Asia, milk consumption is close to 25 kg/year/per capita, in South Asia, close to 52 kg/year/per capita, in sub-Saharian Africa, about 30 kg/year/per capita, in the Middle East and North Africa, about 87 kg/year/per capita, and in Latin America, it is about 113 kg/year/per capita [18].

Malnutrition is responsible in developing regions for about 55% of children's deaths under the age of 5 years [19]. The optimal food for infants is human milk; the World Health Organization (WHO) recommends exclusive breastfeeding for the first 6 months, possibly until the first year of life, while infant formula with a chemical composition similar to human milk is the recommended replacer when breastfeeding is not possible [20]. However, after 6 months of age, breast milk alone does not provide enough nutrients to permit a regular growth of the infant; during the transition period from exclusive breastfeeding to the end of breastfeeding, the risk of lack of nutrition is high [21].

Camels are mammals that ruminate, even if they are considered semi-ruminants because they have a stomach with three compartments with digestive physiology similar to ruminants [22]. They belong to the order *Artiodactyla*, suborder *Tylopoda*, family *Camelidae*. Camels originate and live in arid and semi-arid lands, but due to their special thermal regulation, they do not lose water; in fact, camels regulate body temperature on two levels, with a body temperature of about 40 °C in the heat of the day, while during the night, their body temperature falls to 34 °C [23]. Digestion in camel is more effective, compared with other ruminants; high digestibility of dry matter and fiber is due to the longer retention time and movement of large particles in its fore stomach [24].

In several arid and semi-arid areas around the world, heat, scarcity of water, and natural resources affect the health and milk yield of dairy cows. In these circumstances, camelids play major roles in supplying milk for the local nomadic populations [25]. Two species of camels are known: the dromedary or Arabian camel (*Camelus dromedaries*), one-humped, most diffused around different areas of Africa and Asia (about 24 million heads), and the Bactrian camel (*Camelus bactrianus*), two-humped, accounting for only 3 million heads [26]. Camel milk production in 2017 was estimated to be about 3 million tonnes in the world, representing about 40% of milk production in Somalia, 17% in Mali, and 12% in Ethiopia [27]. To improve milk productivity of the double-humped Bactrian camel, hybridization between dromedary and camel is regularly performed in some areas such as Kazakhstan [28].

Table 1 shows the chemical composition of different mammalian species. Female mammals produce specific milk able to completely fulfill the nutritional requirements of the newborn. Milk is not just a source of nutrients, but it is also able to provide peculiar molecules with bioactive functions and contributes to newborn growth and health [29]. Basically, milk produced by different mammals contains the same major ingredients, but according to the specific differences in nutritional requirements, milk composition is targeted for each single mammalian species [30].

Table 1. Milk chemical composition.

Mammal	Energy (kcal/100 g)	Fat (g/100 g)	Protein (g/100 g)	Lactose (g/100 g)
Human	64.2	3.5	1.2	6.4
Donkey	41.8	0.7	1.6	6.6
Cow	76.2	3.8	3.4	4.8
Sheep	115.7	7.0	5.7	4.7
Goat	74.5	4.1	3.3	4.5
Dromedary	66.1	3.1	3.5	4.4
Bactrian camel	88.9	5.3	3.9	4.5

Source: [17].

A female camel can produce from 2 to 25 L of milk per day, depending on the quality and the total amount of food she consumes; the gestation period lasts about 13 months, and lactation ranges between 9 and 18 months [31]. In dairy dromedaries, as well as in donkeys, the udder has small cisterns containing about 19.3% of the total milk [32]. Camel's milk color is normally white opaque, and it is characterized by a faint sweetish odor but sharp taste; some consumers consider it salty [33]. Camel's milk acidity has been determined to be 0.144% lactic acid, the mean value of specific gravity has been detected around 1.029, the freezing point has been established at −0.518 °C, and electrical conductivity has been reported to be 6.08 millimhos [34]. However, camel's milk physical and chemical characteristics are highly influenced by the geographical origin, the camel breed, and obviously by the lactation stage [35]. Camels lactated longer than one year had significantly greater total solid and fat content, respectively, 15.10% and 5.55%, compared with those lactated less than one year, in which have been determined 12.14% of total solids and 3.61% of fat, while protein, lactose, and ash content were not significantly affected by stage of lactation [36].

The somatic cell counts level in camel milk is normally low, compared with dairy cow's milk; in a study performed in Saudi Arabia, SCC varied from 11,000 to 298,000 cells/mL in farm A, using a milking machine, and from 14,000 cell/mL to 643,000 in farm B using the hand milking method [36]. Regarding bacterial load, in the same study, intramammary infections were detected in 12% of the 84 milk samples collected in farm A and in 37% of the milk samples examined from camels in farm B [37].

3. Protein Fractions in Camel Milk

The total protein content of camel's milk is represented for about 80% by caseins, while in the remaining 20%, whey contains several soluble proteins and different bioactive peptides generated by camel's milk proteases such as chymotrypsin A and cathepsin D (Table 2) [38]. The camel caseins (CNs) are αS1-CN, αS2-CN, β-CN, and k-CN; the proportion of each component is αS1-CN, 22% (*w/w*); αS2-CN, 9.5% (*w/w*); β-CN, 65% (*w/w*); k-CN, 3.5% (*w/w*) [39]. Whey proteins constitute 20–25% of total proteins in camel's milk and are mainly composed of α-lactalbumin (α-La), lactophorin, immunoglobulins (Igs), lactoferrin, and lysozyme [9]. Igs content in camel milk is higher, compared with human milk (1.54 vs. 1.14 mg/mL), while lysozyme and lactoferrin are higher in both human and donkey milk [40]. Camel milk is characterized, similar to human milk, by the lack of β-lactoglobulin, one of the major allergenic compounds in cow's milk; this property allows camel milk to be used in infant formula [41].

Amino acid concentrations in milk from different mammalian species are shown in Table 3. In milk from buffalos, cows, and horses, cysteine and methionine are the limiting amino acids, while lysine is the limiting amino acid in camel milk; it is interesting to note that camel milk contains more methionine, valine, phenylalanine, arginine, and leucine, compared with cow milk [43].

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

Protein Fraction	Cow	Goat	Sheep	Camel	Donkey	Human
Total caseins	24.6–28	23.3–46.3	41.8–52.6	22.1–26.0	6.4–10.3	2.4–4.2
Total whey proteins	5.5–7.0	3.7–7.0	10.2–16.1	5.9–8.1	4.9–8.0	6.2–8.3
Caseins/whey proteins ratio	82:18	78:22	76:24	73.2:76.2	56:44	29.7:33.7
αS1-Casein	8.0–10.7	0–13.0	2.4–22.1	4.9–5.7	Present	0.77
αS2-Casein	2.8–3.4	2.3–11.6	6.0	2.1–2.5	Present	Absent
β-Casein	8.6–9.3	0–29.6	15.6–39.6	14.4–16.9	Present	3.87
k-Casein	2.3–3.3	2.8–13.4	3.2–12.2	0.8–0.9	Present	0.14
β-Lactoglobulin	3.2–3.3	1.5–5.0	6.5–13.5	Absent	3.3	Absent
α-Lactalbumin	1.2–1.3	0.7–2.3	1–1.9	0.8–3.5	1.9	1.9–3.4

Source: [42].

Table 3. Amino acid concentrations (g/100 g protein) in milk from different mammalian species.

Amino Acid	Cow	Sheep	Goat	Camel	Donkey	Human
Aspartic acid	7.8	n.d.	7.4	6.9	8.9	8.3
Threonine	4.5	4.2–4.4	5.7	4.1	3.6	4.6
Serine	4.8	n.d.	5.2	4.3	6.2	5.1
Glutamic acid	23.2	n.d.	19.3	18.1	22.8	17.8
Proline	9.6	n.d.	14.6	12.0	8.8	8.6
Cysteine	0.6	0.8–0.9	0.6	1.9	0.4	1.7
Glycine	1.8	n.d.	2.1	2.1	1.2	2.6
Alanine	3.0	n.d.	3.6	2.1	3.5	4.0
Valine	4.8	6.2–6.4	5.7	4.1	6.5	6.0
Methionine	1.8	2.7	3.5	2.0	1.8	1.8
Isoleucine	4.2	4.6	7.1	4.9	5.5	5.8
Leucine	8.7	9.7–9.9	8.2	6.1	8.6	10.1
Tyrosine	4.5	3.7–3.8	4.8	3.1	3.7	4.7
Phenylalanine	4.8	4.2–4.3	6.0	4.0	4.3	4.4
Histidine	3.0	n.d.	5.0	2.1	2.3	2.3
Lysine	8.1	7.7–7.8	8.2	4.0	7.3	6.2
Arginine	3.3	n.d.	2.9	2.0	4.6	4.0
Tryptophan	1.5	n.d.	n.d.	n.d.	n.d.	1.8
Limiting amino acid	Cysteine Methionine	—-	—-	Lysine	Cysteine Methionine	—-

Source: [43]; n.d.: not detected.

4. Lipid Fractions in Camel Milk

Human milk fat, compared with ruminants' milk, is characterized by lower content of saturated fatty acids (SFAs), higher content of both monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs), a higher ratio ω-6/ω-3 essential fatty acids, and higher cholesterol content; the conjugated linoleic acid (CLA) content is similar in human and ruminant milk (Table 4). Camel milk, compared with dairy cow's milk, shows higher content of long-chain fatty acids and, consequently, a lower amount of short-chain fatty acids [41]. Fat content in camel's milk is quite low, and it is mainly (96%) represented by triglycerides; the average size of its fat globules is smaller, compared with fat globules from ruminants' milk, and for this reason, it is highly digestible [44].

Table 4. Fatty acid profile (% of total fatty acids) and cholesterol content in milk of different mammalian species.

Fatty Acids	Cow	Sheep	Goat	Camel	Donkey	Human
SFA (%)	55.7–72.8	57.5–74.6	59.9–73.7	47.0–69.9	46.7–67.7	39.4–45.0
MUFA (%)	22.7–30.3	23.0–39.1	21.8–35.9	28.1–31.1	15.3–35.0	33.2–45.1
PUFA (%)	2.4–6.3	2.5–7.3	2.6–5.6	1.8–11.1	14.2–30.5	8.1–19.1
ω6/ω3	2.1–3.7	1.0–3.8	4	n.d.	0.9–6.1	7.4–8.1
CLA (%)	0.2–2.4	0.6–1.1	0.3–1.2	0.4–1.0	n.d.	0.2–1.1
Cholesterol (mg/100 mL milk)	13.1–31.4	14.0–29.0	10.7–18.1	31.3–37.1	n.d.	14.0–20.0

Source: [43]; n.d.: not detected.

5. Minerals and Vitamins in Camel Milk

Dry matter in milk shows an ash fraction representing mineral concentrations; in camel's milk, total minerals range between 0.60% and 0.90%, which represents the same range determined in cow's milk [26]. Calcium, phosphorus, and potassium are the most represented minerals in milk, which are basically designed for bone growth and the proper development of newborns, while iron, zinc, and copper are present in small amounts, except camel milk, which is the richest in these minerals (Table 5); milk is considered the main source of calcium in human diets [45].

Table 5. Mineral concentrations in milk from different mammalian species.

Macroelements (mg/100 g)	Cow	Sheep	Goat	Mare	Camel	Human
Calcium	122.0	195–200	132–134	132.7	114–116	33.0
Phosphorus	119.0	124–158	97.7–121	88.4	87.4	43.0
Potassium	152.0	136–140	152–181	66.5	144–156	55.0
Magnesium	12.0	18–21	15.8–16.0	10.2	10.5–12.3	4.0
Sodium	58.0	44–58	41–59.4	19.8	59.0	15.0
Microelements (µg/100 g)						
Zinc	530.0	520–747	56–370	270.0	530–590	380.0
Iron	80.0	72–122	7.0–60	37.0	230–290	200.0
Copper	60.0	40–68	5.0–80.0	64.0	140.0	60.0
Manganese	20.0	5.3–9.0	3.2–6.53	n.d.	80.0	70.0
Iodine	2.1	10.4	2.2	n.d.	n.d.	7.0
Selenium	0.96	3.1	1.33	n.d.	n.d.	1.52

Source: [43]; n.d.: not detected.

Vitamins are organic molecules necessary to the body in small amounts but cannot be synthesized by the body [44]. The dose of vitamins required for growth and body health differs between species. A vitamin necessary in the diet of one species may be regularly synthesized by other species. For example, vitamin C is required only in diets for primates and guinea pigs; other animal species can synthesize ascorbic acid because they have the enzyme gluconolactone oxidase, necessary for vitamin C synthesis. Vitamins may be classified based on their solubility: Water-soluble vitamins are the B group B_1, B_2, B_3, B_5, B_6, B_8, B_9, B_{12}, and ascorbic acid (vitamin C) while the fat-soluble vitamins are retinol (vitamin A), calciferol (vitamin D), tocopherol (and related compounds, vitamin E), and phylloquinone (and related compounds, vitamin K). Vitamin C and vitamin E are primarily antioxidants. Goat milk is rich in vitamin A and some from the vitamin-B group, but it shows a significantly lower amount of vitamin B_{12} and folic acid, compared with dairy cow's milk (Table 6). Camel milk is characterized by a higher concentration of vitamin

C, compared with dairy cows and human milk [45,46]. In fact, in desert areas, fruits and vegetables are scarce, so camel milk represents, in most cases, the main source of vitamin C in the diet of nomadic populations living in those regions [47].

Table 6. Vitamin contents in milk from different mammalian species.

Vitamin	Goat	Sheep	Cow	Camel	Human
Vitamin A (μg/100 g)	185	146	126	26.7	190
Vitamin D (μg/100 g)	2.3	1.18	2.0	0.3	1.4
Vitamin B_1 (mg/100 g)	0.07	0.08	0.05	0.05	0.02
Vitamin B_2 (mg/100 g)	0.21	0.38	0.16	0.17	0.02
Vitamin B_3 (mg/100 g)	0.27	0.42	0.08	0.77	0.17
Vitamin B_5 (mg/100 g)	0.31	0.41	0.32	0.37	0.20
Vitamin B_6 (mg/100 g)	0.05	0.08	0.04	0.55	0.01
Vitamin B_8 (μg/100 g)	1	5	5	87	5.5
Vitamin B_9 (μg/100 g)	1.5	0.93	2	n.d.	0.4
Vitamin B_{12} (μg/100 g)	0.07	0.71	0.36	85	0.03
Vitamin C (mg/100 g)	1.29	4.16	0.94	33	5.0

Source: [43]; n.d.: not detected.

6. Therapeutic Properties of Camel Milk

6.1. Hypoallergenic Properties of Camel Milk

Camel milk, similarly to human milk, lacks β-lactoglobulin, which is considered one of the major allergenic milk proteins (Bos d5) [44]. The β-casein content (Bos d8) of camel milk is lower than that of cow milk but similar to that of human milk [46]. Furthermore, milk proteins from camel and cow show a low protein sequence identity (ranging from 47% to 81%) [47]. The hypoallergenic properties of camel milk have been proven by several authors through immunoblotting experiments, providing evidence that patients affected by cow's milk protein allergy (CMPA) did not recognize camel milk after administration of camel milk in pediatric patients over the age of one affected by CMPA [48]. Restani et al. [48], in a study involving 15 CMPA patients fed with camel's milk, did not find in these subjects mediated or nonmediated IgE symptoms and found that camel milk had the same tolerability as the amino acid formulas. A similar result has been also found in a study involving 28 children affected by CMPA to whom it was administered camel milk [5]. Finally, a study indicated that there is a low cross-reactivity between the milk proteins of camel and cow milk, indicating that the similarity between these proteins is low [46]. Taken together, these results seem to indicate that camel milk can be considered as a valid alternative to cow's milk for infant feeding. To further prove the hypoallergenic properties of camel's milk, in this study, milk protein sequence alignment from different species was carried out, with particular attention to the sequence regions identified as IgE and IgG allergenic epitopes of β-caseins, which have been found in CMPA patients [48,49]. The region of the bovine β-caseins amino acid sequence that shows the high intensity of IgE binding is VVVPPFLQPEV, whereas the regions with the highest intensity of IgG binding are MPIQAFLLYQEPVLGPVRGPFPII and LPLPLLQSWM and were recognized by all the allergic patients [49,50]. For this purpose, the protein sequences of β-casein from cow, goat, sheep, camel, human, donkey milk were downloaded from Protein-NCBI (https://www.ncbi.nlm.nih.gov/protein/, accessed on 1 December 2021), and sequence alignments were performed only on the above-mentioned amino acid regions identified as IgE and IgG allergenic epitopes. The results shown in Figure 1 evinced that the cow milk β-casein region MPIQAFLLYQEPVLGPVRGPFPII has high sequence homology with the same amino acid region of the goat and sheep β-casein (highlighted by the red box), but interestingly, it differs considerably from the camel human and donkey milk sequence.

```
Human     VPVQALLLNQELLLNPTHQIYPVTQPLAPVHNPISV
Camel     MPVQAVLPFQEPVPDPVRGLHPVPQPLV----PVIA
Donkey    TPVQAFLLYQDPQLGLTGEFDPATQPIVPVHNPVI-
Goat      DPIQAFLLYQEPVLG------PVRGPF-----PILV
Cow       MPIQAFLLYQEPVLG------PVRGPF-----PIIV
Sheep     MPIQAFLLYQEPVLG------PVRGPF-----PILV
            *:**.*  *:   .      *.  *:     *:
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Figure 1. Sequence alignment of β-casein region MPIQAFLLYQEPVLGPVRGPFPII from the bovine, donkey, human, goat, and sheep milk. Sequences were obtained through the CLUSTAL multiple sequence alignments by MUSCLE (3.8) at https://www.ebi.ac.uk/Tools/services/web_muscle/toolform.ebi, accessed on 1 December 2021. The asterisk (*) indicates the amino acids that are conserved between sequences.

Considering that the other region of the cow milk β-casein characterized high intensity of IgE binding VVVPPFLQPEV, the sequence alignment, shown in Figure 2, offered evidence of a similar situation with high sequence homology between cow, sheep, and goat (highlighted by the red box), while interesting differences can be noted between the amino acid region of the cow and the three sequences of camel, donkey, and human.

```
Human     -AVVLPVPQPEI
Donkey    QPPIVPFLQPEI
Camel     -AVMVPFLQPKV
Cow       -VVVPPFLQPEV
Sheep     -VVVPPFLQPEI
Goat      -VVVPPFLQPEI
              : *. **::
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Figure 2. Sequence alignment of β-casein region VVVPPFLQPEV from the bovine, donkey, human, goat, and sheep milk. Sequences were obtained through the CLUSTAL multiple sequence alignment by MUSCLE (3.8) at https://www.ebi.ac.uk/Tools/services/web_muscle/toolform.ebi. (accessed on 2 December 2021). The asterisk (*) indicates the amino acids that are conserved between sequences.

Finally, the LPLPLLQSWM region of the cow milk β-casein with high intensity of IgG binding was found to be very close to all of the considered species.

The allergenic epitopes of bovine αs1-casein recognized by human IgE and IgG have been reported [50]. The detected major epitopes corresponded to the following amino acid sequence: NLLRFFVAPFPE, GYLEQL, and ELAYFYPELF. Sequence alignments of αs1-casein from goat, sheep, camel, human, and donkey milk were also performed, and the results are shown in Figure 3.

There is high sequence homology for the three major epitopes of αs1-casein (presented in Figure 3 by a red box) between cow, sheep, and goat, but the same regions yielded different results in the human, donkey, and camel. Taking together, these sequence alignment data suggest that camel milk, similarly to donkey milk, has potentially low immunogenicity.

It has been demonstrated that children with severe food allergies improved rapidly after drinking camel milk. This is because camel milk protein peptides are responsible for preventing and treating food allergies; this milk does not contain beta-lactoglobulin, shows a different beta-casein, and possesses immunoglobulins similar to those in human milk, reducing children's allergic reactions and reinforcing their future response to foods [51].

Figure 3. Sequence alignments of αs1-casein from the bovine, donkey, human, goat, and sheep milk. Sequences were obtained through the T-Coffee, a multiple-sequence alignment package [49]. The asterisk (*) indicates the amino acids that are conserved between sequences.

6.2. Camel Milk for Autoimmune Disease

Camel's immune system is stronger, compared with humans, and it is different from all other mammalians [52]. There are five classes of human antibodies: IgG, IgM, IgA, IgD, and IgE; the immunoglobulins are macromolecules that have difficulties reaching and penetrating antigens [16]. However, camel's immunoglobulins, because of their small size, pass into the milk and are transferred into the human blood; in this way, camel milk will work against autoimmune diseases, increasing the defenses of the immune system [53].

6.3. Camel Milk in the Treatment of Autism

Normally, caseins are broken down into amino acids in the intestine; however, it has been shown that, in the case of autism, caseins (primarily β-casein) and β-lactoglobulin, are broken down into casomorphine and other opioid peptides rather than into amino acids [35]. This abnormal milk proteins breakdown is the cause of the so-called morphine-like symptoms. Casomorphine is a powerful opioid stronger than morphine, causing typical cognitive and behavioral symptoms, and eventually brain damage, including autistic-like symptoms [54]. Autistic children drinking camel milk showed significant improvement in their behavior because this food does not contain β-lactoglobulin, and β-casein is present in small amounts, so camel milk does not cause autism symptoms [55].

6.4. Camel Milk in the Treatment of Tuberculosis and MDR Tuberculosis

Tuberculosis is an infectious disease caused by *Mycobacterium tuberculosis*, which lowers the body's immune defense, exposing the infected person to an increased risk of developing other diseases. If the bacteria become resistant to more than one drug, this is called multi-drug-resistant tuberculosis or MDR-TB [17]. Camel milk has a beneficial effect on treating TB, especially MDR-TB [56]. In a clinical trial, a cohort of 14 male patients suffering from tuberculosis for the past 7–8 years was divided into two groups, T1 and

T0. The T1 group received a diet supplement with raw camel milk (1 kg/day), while the T0 group received dairy cow's milk for 10 weeks. Results obtained at the end of the trial showed a positive benefit of camel milk supplementation in TB patients. The authors suggested that camel milk possesses protective proteins enhancing the immune defenses mechanism, destroying *Mycobacterium tuberculosis*.

6.5. Camel Milk in the Treatment of Diabetes

Diabetes mellitus type 1 (T1DM) is a form that results from autoimmune destruction of insulin-producing beta cells of the pancreas; the subsequent lack of insulin causes an increase in glucose in blood and urine [57]. Camel milk, as a therapy for insulin-dependent diabetes mellitus, has been tested in a comparison between conventionally treated diabetes and patients drinking camel milk; the group drinking camel milk showed a significant decrease in blood sugar [58]. The hypoglycemic effect of camel milk has been demonstrated by several in vitro and in vivo studies using animal models or human patients affected by type 1 and 2 diabetes. In general, the effect of camel milk is reflected in an increment in insulin secretion, decrement in insulin resistance, and improvement of the lipid profiles. More specifically, camel milk may have a direct effect on the function of the insulin receptors and glucose transport, it may influence the secretion of insulin by the pancreatic β-cells, and may influence the overall activity of the pancreatic cells [59]. The effect of camel milk on insulin receptors seems to be due to the presence of insulin-like proteins that act directly on the tissue sensitivity to insulin. These insulin-like proteins are stable, resist proteolysis, are not degraded by the acid environment of the stomach, and therefore, can reach the target tissues [60,61]. Another hypothesis is that camel milk has specific proteins and bioactive peptides that may have an indirect action on insulin synthesis and secretion by the β cells of the pancreas. Furthermore, several studies showed that the anti-inflammatory and antioxidative effects of camel milk may help to restore the overall functioning of pancreas β cells [62,63].

7. Discussion

Camels are very resistant animals, because of their physiological and anatomical characteristics; they can live in harsh environmental conditions, including life in the desert, where they often represent the only source of milk, meat, and labor for desert people [64]. Recently, in the United Arab Emirates, camel farming has been gradually transformed from the traditional extensive systems to modern semi-intensive or even intensive systems [65]. However, most camels are still raised under a nomadic management system, continuously moving in search of food. Camel milk is rich in vitamins, minerals, proteins, and immunoglobulins, compared with cow milk, while it shows lower fat and lactose content, compared with bovine milk [66].

Although camel milk dry matter shows a similar chemical composition, compared with dairy cow's milk, their protein profiles are very different. In fact, β-lactoglobulin, the major component of bovine milk protein, has not been detected in camel milk; furthermore, camel milk shows more porous deposits, compared with bovine milk. Recent advances obtained from several studies regarding knowledge about camel milk characteristics could lead to further investigations in order to determine the interactions among different camel milk proteins, particularly serum albumin, lactalbumin, and caseins, to better understand the therapeutic properties of camel milk.

Considering camel's milk protein fractions, β-casein is the most abundant casein, followed by αs1 and αs2, while κ-casein represents less represented fractions [18]. The average size of casein micelles is significantly larger, compared with cow's milk, which leads becomes problematic in cheese making, due to a poor coagulation aptitude [67]. For these reasons, camel milk products are still limited mainly to fermented milk products, such as *gariss* in Sudan, *suusac* in Kenya and Somalia, *shubat* in Turkey, and *dhaanan/ittitu* in Ethiopia [68,69].

In conclusion, camel milk shows several medicinal properties; in particular, it is considered to be an anti-infectious, anticancerous, and antidiabetic functional food. It is used as a source of energy for convalescents. Camel milk can be administered in the treatment of infectious diseases such as tuberculosis in humans [70]. In Kazakhstan, camel milk is also added during chemotherapy for the treatment of cancer of the digestive tract. In diabetic patients, the results indicate that glycemic levels are better balanced after the use of camel's milk.

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