



Camel Milk: Nutritional Composition, Functionality and Health Benefits-A Mini Review

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Abstract

A comprehensive mini-review on camel milk nutritional composition in comparison with bovine milk and an overview of functional properties as antioxidant, antimicrobial and Angiotensin Converting Enzyme (ACE)-inhibitory activities is provided. Camel milk and its protein fractions as lactoferrin and α -lactalbumin were found to provide various potential health benefits including anti-carcinogenic effect, hypocholesterolaemic effect, anti-diabetic, anti-autism and hypoallergenicity effects. Detailed investigations on beneficial impact of camel milk as well its nutrition value was investigated for the improvement of camel milk production and consumption worldwide not only in the arid countries and the hot regions.

Keywords: Camel milk; Proteins; Bio-functional properties; Human health

Introduction

Camel milk plays a key role in human nutrition in hot regions and the arid parts of the world for centuries. Recently, there has been a growing interest in this milk as a potential alternative to bovine milk due to its high nutritional value and therapeutic effects [1]. According to the latest Food and Agriculture Organization (FAO) statistics [2], camel (both species) milk production in the world is reported to be around 3.14 million tonnes per year representing 0.4% of the total milk production of the world, whereas the cow milk production represent 81% of total milk production (683.2 million tonnes per year). Somalia is currently considered as the biggest producer of camel milk worldwide (0.96 million tonnes) followed by Kenya (0.85 million tonnes) [2]. In Tunisia, total camel milk production is estimated to be around 1093 tonnes per year, representing only 0.1% of total milk production in Tunisia [2]. Because of its limited production, camel milk has not been given as much attention in research when compared with bovine milk. Most of the research conducted on camel milk in the past was mainly focused on their physico-chemical characteristics. However, the recent studies have mainly concentrated on the compositional, techno-functional and functionality of camel milk as well as its

protein fractions [3-6]. Several reviews have been published on camel milk (e.g., [1,7,8]). This mini-review summarizes the available information of camel milk with emphasis on nutritional composition, bio-functional activities and its role in human nutrition.

Nutritional composition of camel milk

Camel milk is reported to provide different nutritional components such as vitamins, minerals and essential amino-acids. In the last decades, several studies have shown that camel milk contains various hydro-soluble and fat-soluble vitamins, such as vitamins A, C, D, E and B group with an overall vitamin content around 3.7g/L [9-11]. Camel milk is distinguished by its high amount in vitamins B3 (niacin) as well as vitamin C whose content is five times higher than that of bovine milk (24-52mg/L) [10,12] and which constitutes an important nutritional contribution for people living in the desert areas where fruits and vegetables are not available [7]. Like cow milk, camel milk is an important source of various minerals, especially calcium, magnesium, potassium, phosphorus and sodium. The total mineral content ranges between 6 and 9g/L of milk with an average value of 7.9g/L and 7g/L for

camel and bovine milk, respectively [13]. The content of Ca, Mg and P of camel milk were similar to those of bovine milk. While the minerals Na, Fe, K, Mn and Cu in camel milk were significantly higher as compared to bovine milk [7,9,14]. Fe plays a key role in various biological systems such as oxygen transport and storage and DNA synthesis. While Mn has an essential role in cellular metabolism, it is important for the function of many enzymes as those for cell protection from free-radical damage [15,16].

Fat fraction in milk is mainly present in fat globules which are resistant to pancreatic lipolysis unless they are firstly subjected to gastric digestion [17]. The lipid content of camel milk is about 3.5% [13]. Previous works reported that the fat of camel milk contains a higher amount of fatty acids with long chain (C14-C22) and lower quantity of short chain fatty acids when compared to bovine milk. Furthermore, it contains more unsaturated fatty acids than bovine milk, especially the essential fatty acids [11,18]. However, the average cholesterol content in camel milk fat fraction (~34.5mg/100g) is higher than cholesterol content of cow milk (~25.6mg/100g) as well as the cholesterol of other mammalian species [10,19]. Protein is the key fraction of camel milk which has a significant effect on its nutritional benefits [1]. Camel milk proteins are a collection of different proteins which vary in structure and characteristics. They are classified according to their solubility into whey protein and caseins representing 26.9% and 73.1% of total proteins, respectively [5]. Casein is reported to be digested easily in intestine and it is a known source of amino-acids for development and growth of kids. Camel caseins are characterized by different proteins proportions when compared to bovine milk and milk from other mammalian species. For instance, Camel milk has higher β -casein amounts representing 44% and 37.4% of total camel and bovine milk proteins, respectively. Camel caseins have also lower κ -casein and α S1-casein amounts than those of cow milk [20]. The high percentage of β -casein reflects the higher digestibility rate of camel milk and lower incidence of allergy to infants; indeed, β -casein is more sensitive to peptic hydrolysis than α -casein [21]. For the soluble fraction of camel, milk, camel whey is reported to be totally devoid of the β -lactoglobulin which is the major whey protein of bovine milk representing more than 50% of total bovine whey proteins [22,23]. While for camel milk the α -lactalbumin is the main whey protein representing 72.8% of total camel whey protein followed by Camel Serum Albumin (CSA) (7.8%) and lactoferrin (4.1%) [6,24-26]. Camel α -lactalbumin is reported to be more nutritious than its bovine counterpart. Indeed, it possesses a high concentration of the essential amino-acids especially Trp, Cys and Lys residues. Camel and bovine α -lactalbumins contain 21.6 and 19.6% of these amino-acid residues, respectively. Camel whey contains also specific protein fractions which are not comparable to any proteins in cow milk as PGRP (Peptidoglycan recognition protein), WAP (Whey Acidic Protein) and CWBP (Camel Whey Basic Protein) [6,26-28].

Camel milk functionality

Several studies have shown that camel milk is an important nutritional and functional source and could provide particular biological activities such as antioxidant, antimicrobial and Angiotensin Converting Enzyme (ACE)-inhibitory properties especially after enzymatic hydrolysis. For instance, whole camel milk protein hydrolysates showed an effective antioxidant potential *in vitro* as well as in real food systems to inhibit lipid peroxidation in fish mince. Papain-produced hydrolysate displayed higher inhibition than hydrolysates from alcalase and bromelain enzymes [29]. Furthermore, Camel milk hydrolysates using pepsin possessed higher ACE-inhibitory and antioxidative properties when compared to cow milk hydrolysates [30]. Meanwhile, after enzymatic hydrolysis with chymotrypsin, purified camel β -casein showed high antioxidant activity. Both of camel caseins and β -casein showed significant ACE-inhibitory activities which were enhanced after hydrolysis with pepsin trypsin and chymotrypsin [31]. On the other hand, Proteases such as α -chymotrypsin and alcalase produced peptides with higher biological activities (both antioxidant and antimicrobial activities) when compared to Papain. However, whole hydrolysates exhibited more functionality compared to fractions obtained after ultra-filtration due to the synergistic effects of the produced peptides or the higher concentrations of peptides in whole hydrolysates as compared to fractions [32]. Native camel caseins (Unhydrolyzed) exhibited significant antibacterial properties against *Escherichia coli* and *Listeria innocua* at a protein concentration of 20g/L and 40g/L, respectively. In the same way, the purified camel β -casein exerted strong antifungal activities towards *Aspergillus tamarii* and *Aspergillus sclerotium* at a protein concentration of 5g/L, while its bovine counterpart no bactericidal activities [33].

For whey proteins, camel α -lactalbumin had higher digestibility degrees with both enzymes trypsin and chymotrypsin when compared with bovine α -lactalbumin, whereas both α -lactalbumins showed similar sensitivity to pepsin enzyme. Camel α -lactalbumin exhibited significant antioxidant activities with respect to antiradical, FRAP and iron chelating activities especially in its apo (calcium-depleted) form because it contains higher antioxidant amino-acids residues when compared to its bovine counterpart [25,34]. Furthermore, camel apo α -lactalbumin had important antimicrobial activities *in vitro* against Gram (-) bacteria (*Pseudomonas aeruginosa*) and against various fungal pathogens species (*Aspergillus sclerotiorum*, *Penicillium bilaiae* and *Aspergillus tamarii*) at a protein concentration of 1g/L. While bovine α -lactalbumin didn't show any antimicrobial activities in this work [25]. These research suggested that camel milk proteins could be used as food ingredients characterized with important antioxidant and antimicrobial activities. It also encourages the use of camel milk and derived proteins and peptides for direct human consumption.

Camel milk and health

Several studies have shown that camel's milk, in addition to its nutritional value, has several benefits in human health due to the presence of bioactive substances, such as vitamins, lactoferrin and immunoglobulins [7]. Indeed, fresh and fermented camel milk is reported to be a potential treatment for several diseases such as dropsy, tuberculosis, asthma, jaundice and leishmaniasis. It is also recommended for diarrhea, constipation and wounds [27,35]. It can even be used to improve ovulation in women. Camel milk camel milk is distinguished by its ability to boost the immune system. Hence, it is beneficial for immune problems such as sclerosis and crohn's infections [1,21]. Further, recent studies have shown that camel milk also ameliorates alcoholic liver injury through its anti-inflammatory, anti-apoptotic and antioxidant [36]. Camel milk is also an ideal treatment to treat children with Autism Spectrum Disorder (ASD). Indeed, health status of the autistic children after camel milk consumption was greatly improved. A significant reduction in the ASD symptoms was observed and hence, autistic children became less destructive and more productive. In other cases, the autistic behavior was completely disappeared [37]. Camel milk has other exceptional therapeutic properties as anti-carcinogenic [38] anti-diabetic [39,40] and anti-hypertensive activities [41]. It is even recommended for allergic children to cow's milk proteins [21]. Fermented camel milk products (Gariss) containing *Bifidobacterium lactis* were reported to possess a hypocholesterolaemic effect *in vivo* in rats [41]. Camel milk consumption also provides effective management for patients having type 1 diabetes as well as for rats [39] due to the presence of high concentration of insulin and insulin like substances in camel milk as half-cystine [39]. Furthermore, epidemiological investigations proved that the consumption of camel milk in different regions has significantly decreased the prevalence diabetes and contributed to the reduction of the needed insulin doses in a rate of 92% for diabetic patients [42]. These properties were explained by the presence of high amounts of antioxidant enzymes and non-enzymatic antioxidants as vitamins A and C in camel milk which may reduce the risk of diabetes diseases [43]. The small size immunoglobulins in camel milk and the lack of coagulation of camel milk in the human stomach also contributed to its hypo-glycemic effect [7].

Recent studies have shown that the combination of camel whey proteins or their hydrolysates with insulin revealed a positive allosteric modulation of human insulin receptor that was drastically reduced by the competitive human insulin receptor antagonist [44]. Different clinical examinations indicated that drinking of camel milk resulted in decline of the formation of disease cells [1]. Indeed, both of fermented and unfermented camel milk have magnificent impact on curing cancer. Fresh camel milk has *in vivo* and *in vitro* anti-cancer effects on breast cancer cells (MCF-7) via the apoptosis, the oxidative/inflammation stress prevention and the tumor models metastasis [45]. Similarly, an isolated camel

whey protein fraction (namely TR-35) exhibited strong *in vitro* and *in vivo* anti-cancer activities against epithelial cell-lines of human esophageal carcinoma [46]. For camel proteins, camel lactoferrin has significant anti-proliferative effects on human breast cancer and colorectal cells via the autophagic death [47]. Camel lactoferrin also inhibited the growth of colon cells and the damage of DNA through binding catalytic iron [38]. Camel α -lactalbumin is able to bind oleic-acid leading to the formation of CAMLET complex (camel α -lactalbumin made lethal to tumor cells). This complex exhibited a significant anti-cancer activity against four cancer cell lines especially breast cancer cells through the induction of selective apoptosis which causes the arrest of the cell-cycle [48]. Both of camel and bovine α -lactalbumins in their oleic-acid complexes are characterized by a reduction tertiary structure and high levels of native secondary structure. However, camel α -lactalbumin is more disordered and possessed stronger aggregation propensities than bovine α -lactalbumin leading to an increase in its lethality against cancer cells [48,49]. In addition to its therapeutic properties, camel milk was also suggested as an alternative to children who suffer from cow milk protein allergy. Indeed, camel milk has special characteristics that strongly differentiate it from other ruminant milks. It doesn't contain β -lactoglobulin which is considered as the most potent cow milk allergen for children sensitive to milk protein, being responsible for allergic reactions in 60 to 80% of total allergic patients [50,51]. Camel milk contains lower amounts of the α S1-casein than cow milk (Figure 1). Further, level of sequence identity of camel proteins with their bovine counterparts is the lowest when compared to milk proteins of other mammalian species (less than 53%) [52]. Hence, the absence of immunological cross-reactions between bovine and camel milk proteins (caseins and whey proteins) was reported [21].

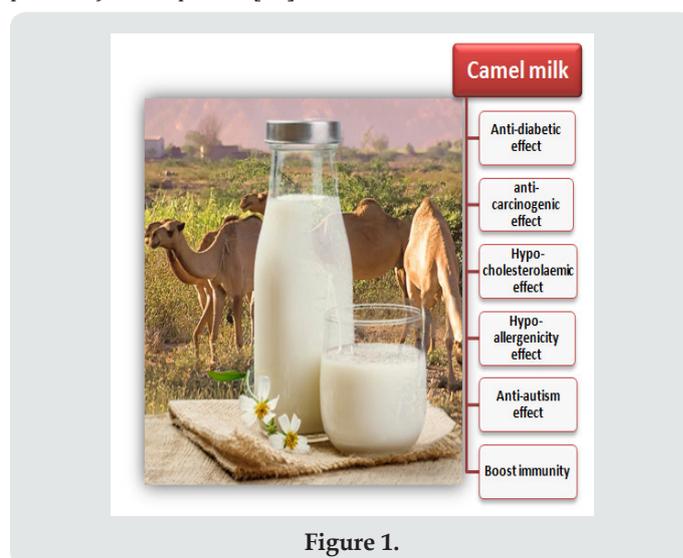


Figure 1.

Conclusion

Research proven that camel milk has valuable nutritional, bio-functional and therapeutic properties. Camel milk and its

products are good source of proteins, vitamins, minerals, fats and different bioactive components which are necessary to fulfill all the requirements of the human nutrition. Camel milk and its proteins fractions are characterized by several biological properties such as antioxidant and antimicrobial activities. Furthermore, camel milk is also beneficial to the health of the consumer by its medicinal characteristics which are not found in bovine milk. Indeed, camel milk can be used for the curing of cancers, diabetes, autism, and several other diseases. This mini-review has summarized the main studied properties of camel milk which may be helpful to spread the consumption of this valuable product.

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