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BIOACTIVE PROPERTIES OF MINOR CAMEL MILK INGREDIENTS - AN OVERVIEW

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ABSTRACT

Camel milk has numerous minor components which have special bioactive properties. These are present at significant concentrations and are beneficial for human diet and health e.g. lactoferrin, serum albumin, lysozyme, mono- and polyunsaturated fatty acids, vitamins B, C and E, manganese, iron, calcium and potassium, different types of immunoglobulins, as well as the hormone insulin and IGF-1. Regarding the importance of camel milk and the related health benefits of the bioactive ingredients, it must be consumed raw, fresh and should be free of pathogens.

Key words: Camel milk, bioactive substances, human health, milk composition

Milk is a complex medium containing a variety of nutrients, proteins, fats, lactose, minerals, vitamins as well as other molecules of functional or bioactive properties. Camel milk is considered one of the most valuable food sources for nomadic people in arid and semi-arid areas and has been consumed for centuries due to its nutritional values and medicinal properties (Dowelmadina *et al,* 2014; Yadav *et al,* 2015; Kaskous, 2016; Kula and Dechasa, 2016). It has high quality of composition and various bioactive ingredients, showing special properties that make it distinct and unique compared to other species milk (Wernery, 2007; Smits *et al,* 2011; Hamed *et al,* 2012; Yadav *et al,* 2015). The mean values of major components in camel milk were reported over the past 30 years: 3.5±0.1 % fat, 3.1±0.5 % protein, 4.4±0.7 % lactose, 0.79±0.07 % ash and 11.9±1.5 % total solids (Al haj and Al Kanhal, 2010). In addition, camel milk contains high amounts of various antimicrobial and bioactive substances, e.g. lactoferrin and various classes of antibodies (Kaskous, 2016; Kula and Dechasa, 2016; Patel *et al,* 2016). Biologically, camel milk is the normal secretion of mammary gland and the most important source of nutrition for new-born camels and also considered as a mine of nutritive chemicals. Differences between camel and bovine milk lead to differences in physiological and biological properties (Jrad *et al,* 2013). Camel milk varies greatly because many external components affect its composition, such as the country or location, feeding conditions, camel breed, type of samples, milking frequency, stage of lactation, parity numbers and more (Abdoun *et al,* 2007; Dowelmadina *et al,* 2014).

Camel milk is most frequently consumed raw and hence unpasteurised, because in the raw form it retains the nutritional and immune properties. However, pasteurisation is highly recommended when the quality and safety of the camel milk is in question. Nonpasteurised camel milk can be a source for various bacteria which may lead to health hazard for humans when it is taken raw without quality or hygiene control (Elhaj *et al,* 2013) and not using clean and well managed milking procedure (Kaskous and Fadlelmoula, 2014). Investigations showed that raw camel milk is highly contaminated when camels are milked under nomadic conditions lacking proper hygiene (Wernery, 2007).

The properties of the individual bioactive camel milk components and its importance are presented and discussed.

Special properties of camel milk proteins

Camel's milk is a rich source of proteins with potential anti-microbial and protective activity. This biological beneficial effect of camel milk protein is primarily combined with minor proteins. Smits *et al* (2011) reported that characteristics of proteins in camel milk differed significantly from those in bovine milk, in terms of molecular mass and hydrophobicity. Camel milk has 21 different amino acids (Tsetsegmaa *et al,* 2008) which produced all the camel milk proteins, compared to 18 amino acids in bovines.

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However, camel milk proteins are classically grouped into 2 main classes: major milk proteins including caseins or whey proteins and minor milk proteins including lactoferrins, lysozyme, lactoperoxidase, serum albumin, whey acidic protein, peptidoglycan recognition protein, small peptides and various classes of immunoglobulins.

It is known that camelids exhibit a whole new class of immunoglobulins, which fundamentally differ from all other known antibodies. El-Agamy *et al* (2009) reported that camel milk proteins have unique patterns that are totally different from cow and human milk. The study showed that the lack of immunological similarity between camel's and cow's milk proteins may be considered as an important criterion of the nutritional physiological and clinical aspects. This leads to improved immune function after camel milk consumption. Further, camel milk consumption can also protect the organism against other external pathogens, bacteria or viruses (Agrawal *et al,* 2009; El-Fakharany *et al,* 2012; Mullaicharam, 2014; Yassin *et al,* 2016; Dubey *et al*, 2016).

Major proteins in camel milk

Caseins represent the most abundant protein fraction of camel milk (Al hag and Al Kanhal, 2010; Hamed *et al,* 2012). It has a relative amount of 1.63-2.76% casein, representing 52-87% of total proteins compared to an average of 83% in bovine milk (Mehaia *et al,* 1995; Khaskheli *et al,* 2005; Frister, 2007; Hamed *et al,* 2012). β-Casein is the main camel milk casein with 59.40±1.04% of total casein compared with 47.77±0.35% in bovine milk casein (Hamed *et al,* 2012). α_{s1}-Casein constitutes about 23.89±0.68% of total casein compared with 38.36±0.37% in bovine milk casein (Kappeler *et al,* 1998) and 3 protein patterns named α_{s1}-Casein A, C and D in camel milk were identified (Erhardt *et al,* 2016). Only 3.48±0.29% of the total casein corresponds to κ-casein in camel milk compared with 7.20±0.41% in bovine milk casein (Hamed *et al,* 2012). Furthermore, α_{s2}-casein constitutes about 11.89±0.49% of total casein compared with 5.35±0.20% in bovine milk casein (Ribadeau-Dumas and Grappin, 1989).

Al hag and Al Kanhal (2010) and Hamed *et al* (2012) reported that camel milk is more similar to human milk since it contains a high percentage of β-Casein. This high percentage could reflect its higher digestibility rate and lower incidence of allergy in the gastro-intestinal-tract (GIT) of infants, as β-Casein is more sensitive to peptic hydrolysis than α_s-Casein (El-Agamy *et al,* 2009). However, casein from dairy cows are metabolised incomplete in the intestines of some people. As a result, short neuroactive peptides, such as beta-casomorphins are formed which are derived from milk caseins. Beta-casomorphins has long been considered as a risk factor for autism (Woodford, 2011). It has been demonstrated that camel milk showed a therapeutic effect in the Autism disease (Shabo and Yagil, 2005; Wernery *et al,* 2012; Yagil, 2013; Al-Ayadhi and Elamin, 2013), because camel milk does not contain beta-casomorphins leading to the autism symptoms when drinking cow milk. Kappeler *et al* (1998) discovered the amino acid sequence differences of camel casein. The number of amino acid (aa) residues in the 4 major caseins subtypes were: β–Casein 217 aa; α_{s1}-Casein 207 aa; α_{s2}-casein178 aa and κ-casein 126 aa.

Whey proteins are the second major group of components of camel milk proteins and constitute 20-30% of the total proteins (Frister, 2007; Wernery, 2007; Al hag and Al Kanhal, 2010; Hamed *et al,* 2012). The composition of camel milk whey proteins is significantly different to that of bovine milk whey (Smits *et al,* 2011). The whey protein β–lactoglobulin, which is the main allergen in bovine milk, could not be detected in camel milk, as also observed for human milk (Merin *et al,* 2001; Wernery, 2007; El-Agamy *et al,* 2009, Smits *et al,* 2011). In camel milk, whey protein α-lactalbumin is the major whey milk component (Wernery, 2007; Al hag and Al Kanhal, 2010), whereas in bovine milk whey, β–lactoglobulin is the main component (50%) and α-lactalbumin is the second (40%) (Frister, 2007).

Minor proteins in camel milk

The milk protein lactoferrin, is an iron-binding glycoprotein, which is one of the elements essential for the proliferation of bacteria (Adlerova *et al,* 2008). Lactoferrin inhibits the growth of iron-dependent bacteria (Boretius, 1986) and is considered to be a part of the innate immune system (Adlerova *et al,* 2008). At the same time, lactoferrin also takes part in specific immune reactions in an indirect way (Legrand *et al,* 2005). Therefore, camel milk lactoferrin is called as a potent natural antibacterial and novel immune-modulator agent (Ismael *et al,* 2013) (Table 1). This natural antimicrobial property is based on a multifunctional bioactive molecule with a critical role in many important physiological pathways. The results of Ismael *et al* (2013) have shown that camel lactoferrin had a significant inhibitory effect against *Escherichia coli, Pseudomonas aeruginosa, Streptococcus agalactiae*

and *Staphylococcus aureus* and lactoferrin increased lymphocyte transformations mean values in a dose dependent manner. The highest transformations mean value was determined at 50 µg lactoferrin per ml camel milk. Anyway, camel lactoferrin have shown its biochemical similarity to human and bovine lactoferrin, as well as the cross-react with the anti-human lactoferrin antibodies (Konuspayeva *et al,* 2007). Redwan and Tabll (2007) showed that incubation of human leukocytes with camel lactoferrin and subsequent infected with HCV (Hepatitis-C-Virus) did not prevent the HCV entry into the cells, while the direct interaction between the HCV and camel lactoferrin leads to a complete virus entry inhibition after seven days incubation. Therefore camel milk with lactoferrin in higher concentrations seems to represents a primary natural produced drug against HCV infection (Redwan and Tabll, 2007). Recently, the potential of camel milk lactoferrin for its ability to inhibit the proliferation of human colon cancer cells (HCT-116) *in vitro* and the DNA damage and its antioxidant activity was evaluated for the first time (Habib *et al,* 2013). Further the antibacterial activity of lactoferrin in the camel milk was intensively researched and described in context of mastitis by Al-Majali *et al* (2007). Compared to bovine milk lactoferrin is present in large quantities in camel milk and the values varied between 0.2 and 7280 mg/ml milk (Qian *et al,* 1995; El-Gawad *et al,* 1996; Elagamy *et al,* 1996; Kappeler *et al,* 1999; Zhang *et al,* 2005; El-Hatmi *et al,* 2006; Konuspayeva *et al,* 2007; Al-Majali *et al,* 2007; Kaskous *et al,* 2012). This fluctuation of lactoferrin concentration in camel milk is influenced by many factors such as udder health. The mean concentrations of lactoferrin from mastitis camels (3.8±0.67 mg/ml milk) was significantly higher than that in normal camels (2.65±0.88 mg/ml milk). Further, the concentration of lactoferrin in 3-4 year old lactating camels showed significantly higher values than that in older camels (Al-Majali *et al,* 2007).

Cameloid Immunoglobulins (Igs)

The group of Igs of camel milk is quite unique in mammals. A further study indicated that camel milk contains a special class of cameloid immunoglobulin's (Ig). The immunoglobulins showed similar spatial structure as human immunoglobulin's (150 kDa), but only $^{1}/_{10^{th}}$ the size around 12-15 kDa (Mullaicharam, 2014). It enables cameloid IgGs an easy and quick targeting of the antigen or surface protein, and subsequently the penetration of a disease microorganism is significantly reduced, which is an advantage compared to bigger immunoglobulin's (Khamehchian *et al,* 2014). Hence it is assumed that camel milk strengthens and supports the gastrointestinal immune system (Kaskous, 2016). In the serum of camel milk, a completely new class of Ig has been discovered which is fundamentally different from all other previously known antibody classes. IgM, IgG, IgA and even IgD have been detected in camel sera. Normally, the structural configuration of the Ig in the milk is characterised by 4 polypeptides, 2 identical H-chains (heavy) and 2 identical L-chains (light) (Frister, 2007) with a size of around 150 kDa. The light chains of the camel milk Ig are completely

Table 1. Antimicrobial effect of camel lactoferrin (cLf) on *E.coli, P. aeruginosa, S. aureus* and *S. agalactiae* counts after 1, 3, 6, 12, 24 hours of incubation.

Type of Bacteria	Items	Microbial count (CFU/ml) after				
		1 hour	3 hours	6 hours	12 hours	24 hours
E. coli	Control	49.000	370.000	2.9×10^6	3.1×10^7	2.7×10^7
	cLf (1 mg/ml)	35.000	15.000	8000	500	CIG
	cLf (3 mg/ml)	CIG	CIG	CIG	CIG	CIG
P. aeruginosa	Control	1.8×10^4	2.3×10^4	1.7×10^5	2.4×10^6	2.9×10^7
	cLf (1 mg/ml)	142.000	111.000	43.000	21.000	17.000
	cLf (3 mg/ml)	107.000	93.000	17.000	950	950
S. aureus	Control	87.000	2.3×10^6	2.7×10^7	2.9×10^8	2.2×10^8
	cLf (1 mg/ml)	73.000	2.1×10^6	2.6×10^7	2.7×10^8	2.1×10^8
	cLf (3 mg/ml)	56.000	1.7×10^6	2.0×10^7	2.1×10^8	1.9×10^8
S. agalactiae	Control	0.7×10^6	2.6×10^6	3.4×10^7	2.9×10^8	3.6×10^8
	cLf (1 mg/ml)	0.4×10^6	1.8×10^6	2.3×10^5	1.8×10^4	2.1×10^5
	cLf (3 mg/ml)	2.2×10^5	1.9×10^5	1.0×10^4	1000	3300

cLf: Camel lactoferrin; CIG: Complete inhibition of growth.

missing (Hamers-Casterman *et al,* 1993). Therefore, camel Igs are significantly smaller than human or bovines and hence called 'nano-antibodies' or just 'nano-bodies'. Camel and llama 'nano-bodies' (12–15 kDa) which is less than a tenth of conventional antibodies (Mullaicharam, 2014). These unique antibodies are far superior to human antibodies as they can neutralise completely enzymes and are active against many viral or bacterial infections. The observation that camel blood is rich in such antibodies classes may explain the resistance of camels against most known animal diseases (Afzal and Sakkir, 1994).

These naturally occurring 'nano-bodies' could be a valuable tool in the control of human disease. Their small size also explains why people respond with defective immune responses so positively to camel milk. However, Camel Igs are able to penetrate into tissues and organs to fight infection and aid repair, where human or bovine Igs cannot due to their size. Katz *et al* (2008) showed that patients with IgE-mediated cow's milk allergy were only 25% tested positive by skin-prick test for cross-reactivity to camel's milk and 75% were negative. The authors suggest that the patients with proven IgE-mediated allergy to cow's milk can utilise to predict suitable alternative sources of milk. It is well known that some foods, such as cow's milk and bovine dairy products, can cause allergic reactions. El-Agamy *et al* (2009) indicated that the absence of immunological similarity between camel and cow milk proteins can be considered the key point in nutrition for children suffering cow milk allergy. In summary, Restani *et al* (1999) and El-Agamy *et al* (2009) found that IgE of children who were allergic to cow milk, do not react after consuming camel milk. They ascribed it to the phylogenetic differences between cameloids and ruminants protein and hence antigen composition (Stahl, 2005).

IgG also showed ability to recognise and inactivate Hepatitis C virus peptides with a significant titer in comparison to human IgG which failed to do it (El-Fakharany *et al,* 2012). In addition, the influence of camel's milk on the immune response in chronic hepatitis B patient has been studied and demonstrated that camel milk can enhance the cellular immune response in the patient and inhibits the replication of the virus DNA and promotes recovery of chronic hepatitis B patients (Saltanat *et al,* 2009). A recent study by El-Fakharany *et al* (2016) reported the influence of camel milk on the Hepatitis C Virus in the infected patients.

Recent research reveals further interesting characteristics in camel milk Igs. The lack of light chain, showed various unique bioactive characteristics and immune system relevant properties: (1) increased cell permeability, (2) ability to cross blood-brain barrier, (3) higher specificity with none to extremely low cross-reactivity, (4) higher thermal stability, (5) higher pH range tolerance, (6) higher water solubility without any aggregation (Niasari-Naslaji, 2010). These peculiarities grab the attention of researchers to use camel immunoglobulin for therapeutic and diagnostic purposes. If successful, the research community could lead to the development of a whole new family of vaccination against some of the biggest killer diseases of our time, such as cancer (Behdani *et al,* 2010). The scientific community speculates and postulates that camel milk Igs could even be an effective treatment against cancer, HIV/AIDS, Alzheimer's disease or Hepatitis C (Martin *et al,* 1997; Agrawal *et al,* 2003; Magjeed, 2005; Shabo *et al,* 2005; Habib *et al,* 2013). Currently, there are still many scientific workgroups are figuring out whether camel milk can also be effective prophylactic against diabetes and heart disease (Zagorski *et al,* 1998; El-Sayed *et al,* 2011; Malik *et al,* 2012; Shori, 2015).

Further immune relevant proteins in camel milk

Besides Igs camel milk contains the following immune relevant proteins in higher qualities than milk from other species, according to Hoelzer *et al* (1998), Mullaicharam (2014), Khamehchian *et al* (2014), Conesa *et al* (2008) and www.nourishinghope.com, 2011 (a selection):

(1) Peptidoglycan Recognition Protein (PGRP) is found in very high concentration in camel milk. It stimulates the hosts' immune response and has antimicrobial activity.

(2) Camel lactoferrin has higher bioactivity compared to cows or goats milk lactoferrin. Lactoferrin prevents microbial overgrowth and invading pathogens.

(3) Lysozyme is an enzyme that is part of the innate immune system that targets gram-positive bacteria.

(4) Lactoperoxidase has bactericidal activity on gram-negative bacteria like *Escherichia coli, Salmonella* and *Pseudomonas*.

(5) N-acetyl-beta-D-glucosamidase (NAGase) has antibacterial activity and is found in similar quantities in human milk.

Lysozyme is among the minor camel milk proteins that has attracted increased attention recently due to its potent antimicrobial activity against a wide

range of micro-organisms and hence potential in food preservation and safety. Lysozyme is an enzyme and it comes in the milk as part of the innate immune system. The lysozyme content in the camel milk ranged between 0.15 to 6.5 mg/l (Barbour *et al,* 1984; Elagamy *et al,* 1996). The concentration of lysozyme in the camel milk varies considerably depending on various factors such as breed, stage of lactation, nutrition, udder health and season of the year. The peptidoglycan cell wall of gram-positive bacteria can be directly attacked by lysozyme (Benkerroum, 2008). Contrary to that of gram-negative bacteria, the outer membrane may be rendered permeable by other components of the innate immune system in the milk, such as lactoferrin, so that they can be attacked by lysozyme. Apart from the direct anti-bacterial effect of lysozyme the release of peptidoglycan fragments leads to a modulation of the immune system via peptidoglycan-recognising receptors. A subset forms the calcium-ion-binding lysozyme, which include for example lysozyme from camel milk.

Lactoperoxidase is an oxidative enzyme that is found in milk of mammals including camel. However, Elagamy *et al* (1992) found that the lactoperoxidase in camel milk acts as a bacteriostatic in gram-positive bacteria strains and as bactericidal in gram-negative cultures. Bolorimoghadam *et al* (2010) also reported that, lactoperoxidase enzyme which extracted from camel milk, has a significant anti-bacterial activity on gram-positive and gram-negative bacteria. Furthermore, lactoperoxidase is destroyed when camel milk and its products are heat-treated at 75°C for 15 seconds. Therefore, this enzyme can be used as an indicator of correct pasteurisation of camel milk (Wernery *et al,* 2013).

Serum albumin in the camel milk comes from the blood. It was shown, that camel milk contained more minor protein than cow milk. This variation is primarily due to the higher content of albumin in camel milk (Al-Alawi and Laleye, 2008). However, Preeti *et al* (2014) found that camel milk has about 7 lower molecular weight bands (electrophoretic pattern), which may be of pre-albumin and other lower molecular weight proteins.

Camel milk protein also contains whey acidic protein (157 mg/l) and peptidoglycan recognition protein (107 mg/l) compared with zero values in both components in bovine milk (Wernery, 2007). Moreover, it was found that fermented camel milk has a special enzyme Angiotensin 1 converting enzyme (ACE) (Quan *et al,* 2008), which facilitates the better proteolytic digestion of the milk proteins, in particular caseins and whey proteins (Alhaj *et al,* 2006). Furthermore, it was found that camel milk and its fermented products have many bioactive peptides. Elayan *et al* (2008) demonstrated that administration of fermented camel milk has a hypo-cholesterolemic effect in rats. Hypocholesterol mechanism of camel milk is still unclear, but different hypotheses were discussed, including: (1) the interaction between bioactive peptides from camel milk and cholesterol levels is derived, which lead to cholesterol-lowering (Li and Papadopoulos, 1998) and (2) the presence of orotic acid in camel milk (arises as an intermediate in the metabolism of the nucleic acids), which is considered responsible for the lowering of cholesterol levels in rats (Rao *et al,* 1981) and in humans (Buonopane *et al,* 1992).

Based on the properties above it can be emphasised that the bioactive peptides derived from camel milk protein had higher functionality including antioxidant activity, anti-hypertension effect and antimicrobial activity comparing to bioactive peptides from bovine milk proteins and therefore, camel milk could be the super food of the future (Salami *et al,* 2010). The problem with camel milk proteins was the stability after sterilisation process, because camel milk has poor heat stability at high temperature and could not be sterilised at natural pH (Alhaj *et al,* 2011).

Properties of lipids in camel milk

Lipids in camel milk as well as their physical and chemical properties were investigated in many scientific studies (Sawaya *et al,* 1984; Abu-Lehia, 1989; Farah, 1993; Gorban and Izzeldin, 2001; Awad *et al,* 2008; Wang *et al,* 2011; Konuspayeva *et al,* 2014) (Table 2). These have shown that the content of short chain saturated fatty acids (C4-C8) is significantly higher in ruminant's milk than in the camel's milk. In addition, the proportion of saturated fatty acids in the camel milk is lower as compared to cow's milk (Hagrass *et al,* 1987; Stahl, 2005; Narmuratova *et al,* 2006; Awad *et al,* 2008). Lipids in the camel milk have a higher proportion of mono- and polyunsaturated fatty acids (Gorban and Izzeldin, 2001; Wernery, 2007; Wang *et al,* 2011; Konuspayeva *et al,* 2014), which enhance its overall nutritional quality (Konuspayeva *et al,* 2008; Ayadi *et al,* 2009). The ratio of unsaturated/saturated acid was more favourable in camel's milk compared to cow's milk or other mammalians (Konuspayeva *et al,* 2008). An advantage over the cow's milk is the ratio of saturated/unsaturated of fatty acids was 1.97 in intensive farming system (Konuspayeva *et al,* 2014). According of Gorban and Izzeldin (2001)

particularly striking is the presence of long chain fatty acids with more than 20 carbon atoms in the fat milk of camels, unlike the cattle. Furthermore, it was shown that short-chain fatty acids (C8:0 and C10:0) were higher proportion in spring and long-chain fatty acids (C17:0 and C17:1) in autumn (Konuspayeva *et al,* 2008). Wang *et al* (2011) reported that unsaturated fatty acids in camel milk were highest than the cow milk, goat milk and human milk and the value were 65.02, 40.76, 40.23 and 58.17 g/100g fatty acids respectively and C18:3 in camel milk (5.12±0.21 g/100g) was significantly higher than the cow milk (0.38 g/100g), goat milk (0.34 g/100g) and human milk (2.96 g/100g). In addition dromedary camel milk had a higher proportion of C17:0iso and C18:1 than bactrian camel milk (Konuspayeva *et al,* 2008). Another study is investigated that C18:3 in camel milk was significantly higher than the cow milk, goat milk and human milk and the value were 5.12±0.21, 0.38, 0.34 and 2.96 g/100g, respectively. Even the higher proportion of linoleic acid (C18:3) in the camel milk can be seen from a nutritional point of view as an advantage. In human, the unsaturated fatty acids play a role particularly in the prevention of cardiovascular diseases. The high content of omega-3 fatty acids and oleic acid, attributed a positive impact on health because through it the level of triglycerides and cholesterol is lowered in the blood (Carrero *et al,* 2004).

Another characteristic of the camel milk fat and its fraction were highly stable against oxidation (up to 20 days) and longer shelf-life (Awad *et al,* 2008). Furthermore, it was found that fat globule size (µm) distribution was similar in cow and camel milk (Farah and Rüegg, 1991) and an average fat globule size diameter ranged from 2.31 to 3.93 µm (Knoess *et al,* 1986). Compared with cow milk, camel milk showed a very slow creaming rate and it had no relationship between the average size distribution of fat globule and they observed poor creaming. This indicated that insufficient quantity of agglutinin in camel milk was mainly responsible for the slow rate of creaming (Farah and Rüegg, 1991).

Table 2. Unsaturated fatty acids (g/100g fatty acids) in camel, human, cattle and goat milk.

Parameter	Camel	Human	Cow	Goat
Unsaturated fatty acids (UFA)	65.02	58.17	40.76	40.23
C18:3	5.12	2.96	0.38	0.34

Properties of sugars in camel milk

Lactose is the main carbohydrate in milk. It is synthesised in the udder from galactose and glucose. The disaccharide lactose in camel milk is present in approximately concentrations of 4.8%, which is easily metabolised by persons suffering from lactose intolerance (Hanna, 2001). Mullaicharam (2014) reported that lactose-intolerant patients often easily digest camel milk. The lower lactose intolerance could be linked to the high concentration in L-Lactate in camel milk, reverse to cow milk, rich in D-Lactate (Baubekova *et al,* 2015). Therefore, camel milk can be considered as an alternative option for the individuals intolerant to lactose (Cardoso *et al,* 2010), which represents today a major market in food industry.

Properties of minerals in camel milk

Minerals at nutritional standard concentrations in foodstuffs are essential for human health. However, when these nutritional values are low or exceeded then humans may get diseases, but on the other hand the consumption of foodstuffs with high mineral contents can cause gastric irritation and diarrhoea (Blunden and Wallace, 2003). Camel milk is well known for its richness in minerals (Farah, 1993; Konuspayeva *et al,* 2008; Al-Wabel, 2008; Al haj and Al Kanhal, 2010; Wang *et al,* 2011; Yadav *et al,* 2015). The total content of minerals in dromedary camel milk was 0.99% (Konuspayeva, 2007) and varies from 0.60 to 0.90% (Konuspayeva *et al,* 2009). The differences in concentration of minerals in the camel milk depends majorly on the feeding, but as well on breed, water intake, season and country or region (Soliman, 2005; Al haj and Al Kanhal, 2010). However, levels of potassium, magnesium, iron, copper, manganese, sodium and zinc are higher in camel's milk than in cow's milk (Sawaya *et al*, 1984; Abu-Lehia, 1987; Yadav *et al,* 2015). Farah (1993) found low levels of potassium and phosphorus in Egyptian dromedaries. Wang *et al* (2011) found that calcium, magnesium and iron content in camel milk were highest than other milk from cows, goats and human. Al-Wabel (2008) has determined some minerals in the milk of cattle, camels, goats and sheep in Saudi Arabia and the results are shown in the table 3.

Camel's milk had the lowest concentration of zinc and there are no significant differences in the concentration of manganese and iron between cattle, camels, sheep and goats. Furthermore, camels have the highest concentration of sodium and potassium compared to other species. It is known that the mineral content of milk raised under hot and dry desert conditions, such as Saudi Arabia. Konuspazeva *et al* (2008) have determined some minerals in the camel milk in Kazakhstan and the mean values

were 1.232±0.292 g/l, 1.003±0.217 g/l and 2.02±1.24 mg/l of calcium, phosphorus and iron, respectively. These concentrations of minerals covered the most daily requirement for adult, when the consumption reached 500 ml per day of camel milk. Soliman (2005) has determined the chemical composition and the minerals in the milk of human, cow, buffalo, camel and goat in Egypt and the results showed that chemical and mineral content of the 5 studied species varied widely. Camel milk contained 0.75 % ash and it is significantly different from buffalo and human milk. Camel milk has the highest Fe, Zn, Na and Cu content than other species. The results of Halima *et al* (2012) showed that camel milk had a very high ash content (0.86 g/l) compared with human milk (0.17g/l). Furthermore, Camel milk is a rich source of chloride (Khaskheli *et al,* 2005). Mehaia *et al* (1995) reported that minerals Na, K, Fe, Cu and Mn in dromedary camel milk were higher than that in bovine milk. This camel milk is plentiful with minerals, which is necessary for the growth, development and human health.

Properties of vitamins in camel milk

Camel milk is known to be a rich source of vitamins, especially vitamin C, which 3 to 5 times higher levels than in cow milk with absolute values up to 40.9 mg/l (Farah *et al,* 1992; Stahl *et al,* 2006, Wernery *et al,* 2005; Haddadin *et al,* 2008; Wang *et al,* 2011). Raw and fermented camel milk could be a good source of vitamin C for the nomads, which are living in the desert where vegetables and fruits are not available. The mean of vitamin C in dromedary camel milk was 34.16 mg/l by Farah *et al* (1992) and 150.4±105 mg/l by Konuspayeva *et al* (2011). This concentration is dependent on many factors such as season (in dry season was 41.0±3.70 mg/l and rainy season was 33.0±4.00 mg/l) (Mohamed and Al-Rasheedi, 2013), stage of lactation (at the first 3 months of lactation was 40.10 mg/l and at 290-360 days of lactation was 44.40 mg/l) (Mohamed and Al-Rasheedi, 2013), the sampling place (Konuspayeva *et al,* 2011), breed (in bactrian camel was richer with 169±110 mg/l than the dromedary with 146±93 mg/l or hybrid with 133±129 mg/l) (Konuspayeva *et al,* 2011). However, Mohamed and Al-Rasheedi (2013) stated that the increase of vitamin C during summer season and with the advancement of stage of lactation could not be justified, and may be related to the unique glucose metabolism of camel.

The loss of vitamin C was very low (6.1%) following pasteurisation of camel milk. This fact can be considered as tremendously advantageous for the consumer in arid and semi-arid countries where vitamin sources are scarce (Wernery *et al,* 2005).

Stahl *et al* (2006) reported that vitamins A, E, B_1, and β-carotene were significantly lower in dromedary milk while vitamin C was significantly higher compared to bovine milk. However, in camel colostrum fat soluble vitamins and vitamin B_1 were higher than in mature camel milk, but vitamin C was lower in colostrum.

Furthermore, the level of niacin in camel milk was found greater compared to cow milk, but thiamine, riboflavin, folacin, vitamin B_{12}, pantothenic acid, vitamin-A, lysine and tryptophan were relatively lower as compared to cow milk (Nikkhah, 2011). Farah *et al* (1992) reported that camel milk contains substantially less vitamin-A (0.10 vs 0.27 mg/l) and B_2 (0.57 vs 1.56 mg/l), and similar vitamin E content (0.56 vs 0.60 mg/l) than cow milk, respectively. However, the content of Vitamin E was similar in camel milk (129.9±26.2 mg/l) and human milk (121.69±15.2 mg/l), but it was the highest (161.0±23.7 mg/l) in fresh cow milk.

Jrad *et al* (2013) reported that camel milk is more acidic and viscous than bovine milk and the protein and non-protein nitrogen (NPN) content in camel milk was significantly higher than that of cow milk. The fractions (NPN) have a biological importance due to their richness in acidic amino acids as well as in Vitamin B.

Table 3. Mineral content (mg/kg milk) of major elements in camels, cattle, goats or sheep milk.

Minerals	Camels	Cattle	Goats	Sheep
Zn	1.48±0.76	2.00±0.28	2.32±0.22	3.09±0.91
Mn	1.30±0.11	1.29±2.43	1.13±0.04	1.14±0.05
Cu	1.61±0.90	1.80±1.10	0.57±0.20	0.62±0.22
Fe	2.98±2.24	4.21±1.78	4.91±2.66	5.01±3.24
Ca	699.30±96.65	661.00±41.95	751.70±72.78	822.50±113.36
Na	115.87±4.99	91.60±3.45	101.30±10.71	95.40±5.47
K	133.77±5.64	113.70±5.84	123.85±9.94	127.41±1.10

Properties of selected hormones in camel milk

Camel milk contains higher average concentrations of insulin (58.67±2.01 UL) as compared to cow's milk (17.01±0.96 UL) (Hamad *et al,* 2011; Mullaicharam, 2014). Wernery (2007) has shown the same results, that insulin in camel milk was present at higher levels (40.5 µU/ml) as compared to cow milk (16.3 µU/ml). Further, camel milk remains unaffected by gastric acid and so passed to the intestine where it can be absorbed bioactive intact by the gastro intestinal tract (Abu-Lehia, 1989; Zagorski *et al,* 1998).

Usually, administration of insulin orally in diabetic patients is not effective, but it seems that insulin in camel milk may be an exception. Thus a study describes the following 3 special properties of camel milk derived bioactive insulin (Malik *et al,* 2012). (1) Camel insulin in camel milk possesses a special property that makes absorption into human circulation easier and cause resistance to proteolysis, compared to insulin from other sources (2) Camel insulin is encapsulated in nanoparticles (lipid micro-vesicles), that allows its passage through the stomach and the entry into the circulation (3) Some up to now unknown elements of camel milk make it anti-diabetic. The protein sequence of camel insulin and its predicted digestion pattern do not suggest differentiability to overcome the mucosal barriers before been degraded and reaching the blood stream. It is further reported, that camel milk contains insulin-like small molecule substances that mimic insulin interaction with its receptor. Shori (2015) concluded that camel milk has a powerful effect in reducing blood glucose levels and insulin requirement and it limits diabetic complications such as elevated cholesterol levels, liver and kidney diseases; decreased oxidative stress and delayed wound healing.

Insulin like growth factor 1 (IGF-1) and Thyroxine (T_4) hormones were determined in the camel milk. It is known, that both hormones play a major role in controlling growth and metabolism. IGF-1 was found at high level around parturition and decreased with stages of lactation, whereas T_4 levels were low at parturition and progressively increased after was (El Khasmi *et al,* 2002).

Conclusions

Regarding the macro and micronutrients of camel milk, it can be concluded that the nutritional value of camel milk is far better compared to cow milk. Camel milk is rich in various minor proteins, nano-immunoglobulins, vitamins, etc. which are not present in cow milk. Camel milk and its proteins do not seem to induce allergies, diabetes and autism as reported for cow milk. An increasing number of scientific publications focus on the nutritional importance of camel milk with its special bioactive components and its beneficial impact on consumer, especially for gastro intestinal health. To ensure complete benefits of camel milk, it must be consumed raw, fresh and free of pathogens as well as after a good and clean milking machine.

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