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FUNCTIONAL PROPERTIES OF CAMEL MILK AND THEIR INFLUENCES ON TECHNOLOGICAL APPLICATIONS

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Abstract

According to the recent statistics by the Food and Agriculture Organization (FAO), the total population of camels in the world is estimated to be about 20 million, with Somalia having the largest herd worldwide. Camels are well adapted to harsh desert climates and can survive without drinking water for days. Therefore, camel (Camelus dromedarius) is of significant socio-economic importance in many arid and semi-arid parts of the world and its milk constitutes an important component of human diets in these regions.
The amounts of lysozyme, lactoferrin, lactoperoxidase and immunoglobulins were found to be greater in dromedary camel milk than bovine or buffalo milk. This property has been shown to be a disadvantage in yoghurt production. As known like yoghurt, cheese is another fermented milk product, due to the activity of these compounds the enzymatic reaction is disturbed and the gelation process of milk is prolonged. These antimicrobial agents were reported to completely lose their activity in camel milk if heat-treated at 100°C for 30 min. But there are contradictional statements about the heating intensity. Therfore in this review on these studies are focussed. In addition the chemical composition of camel milk is compared with another ruminant milks. Camel milk has lots of functional properties. These are antioxidant activity, bioactivity, anti-cancer activity, hypoallergenicity.

Key words: *camel milk, lactoferrin, immunoglobulins, heat treatment, functional properties*

INTRODUCTION

There are about 18 million camels in the world (FAO, 1996) which support the survival of millions of people in arid and semi-arid areas. Meanwhile camel milk is considered one of the main components of the human diet in many parts of the world. Camels were domesticated and developed approximately 5000 years ago and throughout these years have played an integral role in the daily life of camel owners. They are distributed in Africa and Asia, where other livestock farming cannot be easily implemented (Gupta *et al*. 2015). Camels are very resistant animals of hunger and thirtst. Variations in the contents of camel milk may be based on to several factors such as analytical methods, geographical area, nutrition conditions, breed, lactation stage, age and number of calvings (Khaskheli *et al*. 2005). The quality of camel milk and meat, since it contains both valuable essential nutrients, has acquired an important place in human nutrition (Adel *et al*. 2009). According to the recent statistics by the Food and Agriculture Organization (FAO, 2008), the total population of camels in the world is estimated to be about 20 million, with Somalia having the largest herd worldwide (FAO, 2008).
Also according to FAO data the production of camel milk is 5.3 million/liter in the world. At the present time, depending on the camel cultivation camel milk production is also becoming increasingly common.
For this reason, the number of scientific research on camel milk have increased in recent years. They are mainly distributed in African and Asian arid and semi-arid areas, where other livestock farming cannot be easily applied (Gupta *et al*. 2015). Today, camels and their products have been using by humans for transport, traction power, milk, meat, fiber (wool and hair). At the same time, it is used as a raw material for textile industry.

Chemical Composition of Camel Milk

The camel has the ability to produce more milk for a longer period of time in arid zones and dry lands (an environment of extreme temperature, drought, and lack of pasture) than in other domestic livestock species (Yagil and Etzion, 1980).

Geographical root and seasonal variations are factors which influence most changes in composition of camel milk. Camel milk contains 2.9 to 5.5% fat, 2.5 to 4.5% protein, 2.9 to 5.8% lactose, 0.35 to 0.90% ash, 86.3 to 88.5% water, and 8.9 to 14.3% solid-non-fat (SNF) (Khan and İkbal, 2001). Camel milk has similar protein content, lower lactose content (Elamin & Wilcox, 1992), and greater total cholesterol (Gorban and Izzeldin, 1999) compared with cow's milk. Camel milk has greater contents of vitamin C (Mehaia, 1994), ash, and sodium, potassium, phosphorus, zinc, iron and manganese (Gorban and Izzeldin, 1997) than cow's milk.

Seasonal variations also play a significant role in the composition of camel milk, also with camels of the same type and from the same district (Bakheit et al. 2008).

According to other research related to compositional, technological and nutritional aspects of dromedary camel milk the average values of camel milk composition reported from 1980 to 2009 are as follows: protein 3.1%; fat 3.5%; lactose 4.4%; ash 0.79% and total solids 11.9% (Adel et al. 2009). Rates of milk components are based on various types of animals.

Camel's milk is a good source of various vitamins and minerals and it has several medicinal and therapeutic effects and good antibacterial and antiviral properties (Yagil & Etzion, 1980; Balouiri et al., 2016). Some studies showed that camel's milk is an excellent source of components that are involved in some biological activities, such as defence against free radicals and reactive oxygen species. The world's total population of camels was reported to be twenty-two million in 2010 (FAO, 2012) that could produce about 300 million litres milk representing 0.2% of world's total produced milk in 2010 (IDF, 2010).

The amounts of lysozyme, lactoferrin and immunoglobulins were found to be greater in dromedary camel milk than bovine or buffalo milk (Benkerroum, 2008; El-Agamy et al., 2000; Kappeler et al., 1999; Konuspayeva et al., 2007). This property has been shown to be a disadvantage in yoghurt production.

The growth of yoghurt culture in camel milk is delayed due to the presence of lysozyme (Abu-Tarboush, 1996; Jumah, Shaker, & Abu-Jadayil, 2001) which prolongs the gelation process (Jumah et al., 2001).

These antimicrobial agents were reported to completely lose their activity in camel milk if heat-treated at 100°C for 30 min (El-Agamy, 2000).

According to another observations and experiments unlike cow milk, it was found that camel milk can be preserved for a longer time at 30ºC and most importantly the camel milk can be kept at 4ºC for more that three months without any appearing change (Yagil, 1985).

The ability of camel milk to inhibit growth of pathogenic bacteria and its relation to whey lysozyme has been showed by Barbour et al. (1984).

At the same time, camel milk is higher in α-lactalbumin, as it is in human milk compared with cow milk.

Unpublished commercial data reported that some infant formula contains high level of α-lactalbumin in changing to breast feed milk.

Antimicrobial factors of camel and human milk

As shown in Table 1 camel milk is richer in immunoglobulins than human milk. However, its contents of lactoferrin and lysozyme were very low. El-Agamy and Nawar (2000) found that camel milk is contain 1.64 mg/ml of immunoglobulin G versus 0.67, 0.63, 0.70, 0.55 and 0.86 for cow, buffalo, goat, sheep and human milk, respectively.

A comparative study of lysozyme concentration in milk of different species (El-Agamy et al., 1997) showed that camel milk contained significantly higher content of lysozyme than cow, buffalo, sheep and goat but very low content as compared to lysozyme content of human, mare and donkey milks.

The same study showed that camel milk contained also signi ficantly higher level of lactoferrin (0.22 mg/ml) than cow, buffalo, sheep and goat but very low compare with that of human milk.

Table 1. Antimicrobial factors in camel and human milks (El-Agamy et al., 1997)

Antimicrobial factor	Camel milk	Human milk
Mean values ± SD		
Immunoglobulins (mg/ml)	1.54 ± 0.032	1.14 ± 0.055
Lactoferrin(mg/ml)	0.24 ± 0.035	1.95 ± 0.050
Lysozyme(mg/ml)	0.06 ± 0.02	0.65 ± 0.045

Nutritional properties of camel and human milks

Milk of all mammals contains the same principal components, namely water, proteins, fats, carbohydrates, vitamins and minerals, but their content varies widely between ruminant and nonruminant milk. Especially, camel milk contains all essential nutrients as cow milk (El-Agamy et al., 1998). Many components in bovine colostrum and milk exhibit specific biological activity in addition to their established nutritional values. During the past two decades, interest in these beneficial physiological effects and the possibility to utilise the components from milk have increased.

Even between various (non-) ruminants and within a same species the milk composition may differ considerably, given the influence of genetic factors (not only at species but also at breed level), physiological factors (e.g. lactation stage, milking interval), nutritional factors (e.g. feed energy value and composition) and environmental conditions (e.g. location, season). The values should therefore not be viewed as absolute but rather as indicative for the concentration range of milk components. Moreover, methodological differences regarding data collection between consulted papers may contribute to the spread of the presented values.

Therapeutic properties of Camel milk

According to studies, the production of camel milk has significantly increased during the last few years with now pasteurized fresh camel milk in the supermarket. Firstly, camel milk is supposed to have medicinal properties (El-Agamy et al., 1992). In studies camel milk is used jaundice, asthma, in the treatment of various diseases such as tuberculosis and it has been found to be helpful. In addition to this column, cancer, diabetes, hypertension was identified that help to treat their patients (Hossam, 2015). Nowadays, there is a general need to start a number of camel milk based functional products to the commercial markets due to increasing demand in recent years (Al haj *et al*. 2010). These products have to be clinically proven and scientifically evident supported (Ghosh, 2009). Camel milk has lots of functional properties.

These are antioxidant activity, bioactivity, anti-cancer activity, hypoallergenicity activity (Habib et al., 2013). It is also known thar the camel milk has a therapeutic potential against many diseases including cancer. In addition it has long been utilized for its benefit in broad range of diseases like Insulin Dependent Diabetes Mellitus (IDDM) (Agrawal et al., 2002; Agrawal et al., 2003; Agrawal et al., 2005), infant diarrhea (Yagil, 2013), hepatitis (El-Fakharany et al., 2008), allergy, lactose intolerance (El-Agamy et al., 2009; Konuspayeva et al., 2009; Cardoso et al. 2010). It contains extraordinarily high levels of insulin like molecule (Agrawal et al., 2002; 2003; 2005).

Camel milk is emerging as a potent therapeutic alternative which can help in reducing insulin doses in diabetic patients. It's well established role in management of Diabetes has rendered it the title of "white gold of desert". Epidemiological surveys strongly indicate low prevalence of diabetes in communities consuming camel milk. (Agrawal et al., 2013).

Composition of Camel milk colostrum

Colostrum is a complex fluid rich in nutrients and is also characterised by its high level of bioactive components, e.g. immunoglobulins (Igs), especially IgG1, growth factors, especially insulin-like growth factor-1 (IGF-1), transforming growth factor beta-2 (TGF-b2) andgrow th hormone (GH) as well as lactoferrin, lysozyme andlacto peroxidase (Butler, 1994; Pakkanen, 1998; Regester, Smithers, Mitchell, McIntosh, & Dionysius, 1997; Reiter, 1985). Camel colostrum differs in composition from regular milk in that it has a high content of whey proteins, mainly immunoglobulins G (IgG), providing the new-born with immunity.

Camel colostral IgG consists of three main sub-classes, namely IgG1, IgG2, and IgG3 (Azwai et al., 1996) the two latter sub-classes are devoid of light chains and have a molecular mass of 42 and 45 kDa, respectively (Hamers-Casterman et al., 1993). It has been reported that these heavy-chain antibodies interfere with several biological processes and may make it a good candidate for human therapy (Holt et al., 2003). To current knowledge, no information is available regarding the variation in IgG and other major whey proteins in camel colostrum and milk during the first week of lactation.

Antibacterial activity of Camel milk

Camel milk is reported to have an antimicrobial effect against Gram positive and Gram negative bacteria, including *Escherichia coli, Listeria monocytogenes, Staphylococcus aureus* and *Salmonella typhimurium* (Benkerroum et al., 2004; El-Agamy and Khatab, 1992). This inhibitory activity was attributed to the presence of antimicrobial substances in camel milk, including lysozyme, hydrogen peroxide, lactoferrin, Lactoperoxidase and immunoglobulins (El-Agamy and Khatab, 1992). Lactoperoxidase (LPO) is a suitable enzymatic indicator of correct pasteurisation of camel milk and its products are heat-treated at 75 degrees C for 15 seconds (Wernery et al., 2013).

The inhibitory action of camel milk against *L. monocytogenes, S. aureus* and *E. coli* might be attributed to the presence of lactoperoxidase, hydrogen peroxide and lysozyme respectively (Benkerroum et al., 2004). The growth of *Salmonella Typhimurium* was inhibited by lactoferrin in camel milk through binding iron and making it unavailable for its growth (El-Agamy and Khatab, 1992; Ochoa & Cleary, 2009).

Antibacterial activity of Transferrin

Transferrin (TF) is a monomeric glycoprotein of 679 amino acids, with a relative molecular weight of approximately 80 kDa. Transferrin exists mainly in the serum and interstitial compartments of vertebrates and some invertebrates (Baker and Lindley, 1992; Retzer et al., 1996). Transferrin is found at a much lower concentration in human milk (< 50 μg/mL) in comparison with bovine milk (20 to 200 μg/mL) (Schanbacher et al., 1993). The principle physiological function of TF in mammals is to transport ferric irons from sites of absorption to sites of utilization. Transferrin transports iron from the biological fluids into the cytoplasm via plasma membrane by receptor-mediated endocytosis (Pakdman and Chahine, 1997). Transferrin interacts with specific receptors present in variable amounts on target cells. Important target cells include the liver, bone marrow and muscle.

Antibacterial activity of Lactoferrin

Lactoferrin is a mammalian cationic iron-binding glycoprotein belonging to the transferrin family, which was discovered 70 years ago, and isolated simultaneously from human and bovine milks in 1960. Lactoferrin is present in the majority of external secretions and mucosal surfaces, milk being its main source. Lactoferrin binds two atoms of iron and due to this capacity several functions have been attributed to it, such as antibacterial, antioxidant, antitumoral and immunomodulatory (Sanchez et al., 1992).

It is widely distributed in all biological fluids and is also expressed by immune cells, which release it under stimulation by pathogens. Lactoferrin is a multi-functional protein with many beneficial properties, which makes it a functional food for a number of product, commercial and clinical applications (Adlerova et al., 2008). Lactoferrin is a glycoprotein with a molecular weight of about 80 kDa, which shows high affinity for iron. The molecular structure and amino acid sequence of human lactoferrin were discovered in 1984.

Almost all bacteria require iron for their growth; therefore LF devoid of iron is capable of preventing its utilization by some bacteria (Orsi, 2004). A large number of studies have demonstrated the bacteriostatic and bactericidal effect of LF, against a wide range of Gram-positive and Gram-negative bacteria (Farnaud and Evans, 2003). However, other mechanisms besides iron holding can be involved in the antibacterial activity of LF, such as blocking microbial metabolism of carbohydrates or destabilizing the bacterial cell wall (Sanchez et al., 1992).

Antibacterial activity of Lyzozyme

Lysozyme (EC 3.2.1.17; muramidase) is a single polypeptide chain consisting of 129 amino acids, in which lysine is the N-end amino acid and leucine is the C-end one. It is a globular basic protein characterized by molecular weight of 14.3 kDa and cross-linked by four disulfide bonds (Masschalck et al., 2002; Cegielska et al., 2008). It is an important antimicrobial agent in milk, which kills bacteria by cleaving the β-1,4-glycosidic bond between C-1 of N-acetyl muramic acid and C-4 of N-acetyl glucosamine residues of the peptidoglycan in the bacterial cell wall (Zhao, et al., 2011; Li et al., 2011). Lysozyme appears to inhibit not only bacteria where the peptidoglycan layer is a major component of their cell-wall, but also viruses and eukaryotic microorganisms devoid of a typical peptidoglycan layer, suggesting that it acts by other mechanisms of action than the hydrolytic activity (Benkerroum, 2008)

Antibacterial activity of Immunoglobulins

Immunoglobulins in milk immediately brings to mind the relationship between mother's milk, transfer of passive immunity from mother to neonate, and the immature immune system of the neonate. Research in this field dates back to the late nineteenth century, however for many centuries herdsmen have capitalized on the linkage between maternal immune status and the immunological protection and development of the neonate (Butler, Kehrli, 2005; Wheeler et al., 2007). Immunoglobulins in mammary secretions come from several sources and represent a history of the antigen exposure of the mother and the response of her immune system. Immunoglobulins are transported through the mammary epithelial cells by receptor-mediated mechanisms and transferred out of the mammary gland by milk ejection during suckling. The immunoglobulins then enter the environment of the gastrointestinal tract of the neonate. Although that environment is primarily geared toward digestion to gain nutritional benefit, the immunoglobulins remain sufficiently stable to provide protective benefits for the neonate, either through uptake into the vascular system in the newborn of some species or through immunological function in the gastrointestinal tract. The immunoglobulins found in milk and the transfer of passive immunity from mother to neonate have been reviewed by many authors.

Antifungal activity of camel milk components

Regarding the antifungal activity of lactoferrin, the first observation which can be made is that the great majority of research has been carried out on Candida, well known as one of the most dangerous opportunistic pathogens. As for bacteria, the anti-Candida activity of lactoferrin was initially considered as re lated to its ability to bind and sequester environmental iron. But in addition to the iron-chelating activity, a direct interaction between lactoferrin and Candida cells was demonstrated in our Department by Valenti et al. (1986).

Antiviral activity of camel milk components

In a few cases it is reported that lactoferrin failed to prevent virus infection. On the contrary, a long list of virus has been found to be sensitive to the inhibiting action of lactoferrin. This list includes several enveloped viruses such herpes simplex virus 1 and 2 (Hasegawa et al. 1994), human cytomegalovirus (Hasegawa et al. 1994), human immunodeficiency virus (Harmsen et al. 1995), hepatitis B virus (Hara et al. 2002), hepatitis C virus (Ikeda et al. 1998), respiratory syncytial virus (Grover et al. 1997), hanta virüs (Murphy et al. 2000) and four naked viruses: rotavirus (Superti et al. 1997), poliovirus (Marchetti et al. 1999), adenovirus (Arnold et al. 2002) and enterovirus 71 (Lin et al. 2002).

Evaluation of camel's milk from technological aspects

The absence of β-LG might explain some of the differences observed between camel and cow milk regarding technological properties such as thermal stability during drying, heat induced aggregation and adherence to heating surfaces (fouling properties) as well as the thin consistency found in fermented camel milk (Merin et al. 2001; El-Agamy, 2007; El-Hatmi et al. 2007; Laleye et al. 2008).

A detrimental effect of heating on the beneficial health effects of milk, the most frequently cited arguments of raw milk advocates are a reduced susceptibility to allergies, a higher nutritional quality and a better taste. However, the consumption of raw milk poses a realistic microbiological risk for the consumer. The presence of foodborne pathogens has been demonstrated in many surveys and foodborne infections have been repeatedly reported for Campylobacter, Salmonella spp. and human pathogenic verocytotoxin-producing *Escherichia coli* after raw milk consumption (Claeys et al., 2013; O'Mahony, Fanning and Whyte, 2009; Robinson, Scheftel, & Smith, 2014; Verraes et al., 2014).

Whey proteins of bovine milk are less resistant to heat denaturation compared to those of buffalo milk, which in turn are less heat resistant than camel whey proteins (El-Agamy, 2000). Even though camel whey proteins have a higher heat stability than bovine whey proteins at temperatures between 63 and 90°C (Farah, 1986), bovine milk coagulates much slower at higher temperatures. This could be related to the absence or very low levels of β-lg and κ-casein in camel milk (Farah & Atkins, 1992) as milk is more resistant to heat when it is characterized by a molar β-lg to κ-casein ratio close to 1 (Bar1owska, Szwajowska, Litwinczuk, Król, 2011).

In another study is shown that the heat stability of camel milk was relatively lower at high temperature treatments. Heat coagulation time (HCT) in the range 100-130 degrees C was too short (< 2 min). Camel milk heat preservation can be done only by pasteurisation. After LTLT pasteurisation, counts of aerobic total and psychrotrophic bacteria were significantly ($p < 0.05$) reduced and coliforms were not detected (Kouniba et al., 2005).

There are some investigations applied the inactivity of enzymes, which have from the technological sides important. In this case the activity of alkaline phosphatase (ALP), gamma-glutamyltransferase (GGT), lactoperoxidase (LPO), lipase (LIP) and leucine arylamidase (LAP) in raw and pasteurised camel milk was studied, in order, to find a heat treatment indicator suitable to verify an effective pasteurisation. LAP activity in raw camel milk is too low and the data variation is too high for serving as a marker. The LPO results look promising. The enzyme activity in raw camel milk is high and the respective value in pasteurised milk is predominantly below the detection limit of the method.

CONCLUSIONS

The production of camel milk is gradually increasing due to an increased interest by consumers in recent years. Camel milk was found to be different in some aspects from milk of other animal species, such as bovine milk. Use of camel milk is widespread not only during production of different kinds of milk products but also as cure material to heal different kinds of diseases such as cancer, diabetes, hypertension, autism dropsy, jaundice, tuberculosis, asthma.

Except from the therapeutic properties the use of camel milk is investigated in different area. Due to functional properties of some camel milk components such as lactoferrin, lyzozyme and immunoglobulins the camel milk is longer storable than other kinds of ruminants milk. Some of functional properties are called such as antibacterial, antiviral, antifungal, antiallergic exc.

Camel milk is known as an alternative milk source and is widespread in many countries. The production of milk products such as yoghurt, chees, ice-cream, pasteurised milk especially in Somalia and Sudan.

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