Chapter 7
Functional Properties of Camel Milk

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ABSTRACT

This chapter focuses on the potential health benefits of camel milk including angiotension I-converting enzyme-inhibitory, anti-cancer and antioxidant activities, antidiabetic, antimicrobial and hypoallergenicity effects. The bioactivity of oligosaccharide, conjugated linoleic acid and D-amino acid in camel milk is provided. The proposed mechanisms behind these bioactive components and potential health claims are explained. This chapter also describes camel milk composition, nutritional value, production and population. The current available information in the literature on camel milk is not abundant. More research is needed to give better understanding on functional properties of camel milk.

INTRODUCTION

The primary purpose of food including dairy products is to provide nutrients to fulfil the body’s traditional requirements and other functions including cultural and social wellbeing. Although, in the recent decades life style has changed and become more complicated regarding life standard, hygiene, diet, use of antibiotics and other antimicrobial substances, hence a new concept of food need to be introduced. It has long been recognized that some non-traditional foods, for example camel milk, fortified food and beverages that provide particular health benefits and interestingly, in recent decades they have been modified to provide disease-preventive attributes, in addition to their particular functional health benefits. The concept of functional foods has also been developed and their types have been expanded to become one of the popular foods worldwide. The estimated growth rate of functional food in the global market is 15-20% per year, and the industry is claimed to be worth up to US$168 billion of the annual share (Euromonitor, 2010; Hilliam, 2003). However, there is no internationally accepted definition of functional foods exist, because it is a more of a concept rather than a well-defined group of food products (ILSI, 1999). So far, various definitions have been proposed by a number of researchers and/or foundations including International Food Information Council (IFIC) in 2011 as “food thought to provide benefits...
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beyond basic nutrition and may play a role in reducing or minimizing the risk of certain diseases and other health conditions”. The EU official directives have not given functional foods a firm definition, but the International Life Science Institute (ILSI) Europe in 1999 has proposed a working definition as food can be considered as ‘functional’ if it is “satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either an improved state of health and well-being and/or reduction of risk of disease”.

Consumers are now more aware of functional foods than before, in 2013, 46% of consumers strongly agree that certain foods have health benefits beyond basic nutrition (IFIC, 2013). The recent information by IFIC showed that 91% of consumers are aware about the healthfulness of their food and beverages, furthermore, 88% knowledge a lot about food ingredients (IFIC, 2015).

According to the latest statistics of the Food and Agriculture Organization (FAO), the total heads of camels worldwide is estimated to be about 27 million, which mainly live in Africa (82.5%) and Asia (17.5%) (FAOSTAT, 2013). Camels are mainly classified into two species belonging to the genus Camelus; Dromedary camels having one-humped (Camelus dromedarius) are the dominant species which tend to live in the arid regions, whereas Bactrian camel having two-humped (Camelus bactrianus) mainly prefer living in the cooler regions (Al haj & Al Kanhal, 2010). The dairy camels in the world produce about 3 million ton of whole fresh milk per year distributed between Asia (8.7%) and Africa (91.3%), whereas Somalia is the biggest producer worldwide followed by Kenya, Mali, Ethiopia, and Saudi Arabia, respectively (FAOSTAT, 2013). Humans consume only 1.3 million tons per year while remaining amount are fed to calves (FAO, 2008). This is because most of the camel herds are located in the arid and desert regions which are far from the commercial markets. Recently very few camel milk products are available in the urban markets. Nowadays, there is a general need to launch a number of camel milk based functional products to the commercial market due to increasing demand in recent years (Al haj & Al Kanhal, 2010). These products have to be clinically proven and scientifically evident supported (Ghosh, 2009). This chapter focuses on the functional properties of camel milk components as well as proposed mechanism behind each health claim. The compositional and nutritional aspects of camel milk are also highlighted.

BACKGROUND

Camel Milk Composition

Camel milk has an important role in human nutrition in the arid regions; however camel milk is generally described as opaque-white, frothy, sweet and sharp but sometimes salty in taste (Al haj & Al Kanhal, 2010). These variations in taste are due to the type of fodder and unavailability of water (Farah, 1996). Although camel milk shows convergent gross chemical composition compared to other mammalian milks, on the other hand few differences were found in some sub-constituents for example absence of β-Lactoglobulin, high β-casein, and low αs-casein content (Table 1). These differences provide camel milk with some additional functional properties, for example, hypoallergenicity and higher digestibility in the gut of infants (El-Agamy et al., 2009; Abou-Soliman, 2005). Nevertheless, references data (Claeys et al., 2014; Al haj & Al Kanhal, 2010; Konuspayeva et al., 2009) have exhibited wide ranges
of variation in camel milk composition. Since these variations was due to several factors such as analytical measurement procedures, regional locations, stage of lactation, age, nutrient conditions and breeds (Khaskheli et al., 2005; Al haj & Al Kanhal, 2010). The mean values of camel milk composition and range of variation are shown in Table 1.

**CAMEL MILK BIOACTIVITY**

Camel milk is an important nutritional and functional source that consist a complex mixture of high quality proteins, carbohydrates, fats, minerals, and vitamins; which deliver human health with several key bioactive properties (Al haj & Al Kanhal, 2010). Early reports (Abdelgadir et al., 1998; Shalash, 1984) showed that non-fermented or fermented camel milk were used worldwide as a potential treatment for a number of diseases including tuberculosis, dropsy, asthma jaundice and leishmaniasis. Furthermore, children having biliary atresia and postpartum respiratory insufficiency were given camel milk until their liver transplant and lungs developed and function well (Yagil, 1987). These potential health claims were due to a number of bioactive components, which either exist naturally in camel milk (Agrawal et al., 2007; El-Agamy et al., 1992); or encrypted in the primary structure of camel milk constitutes and could be released in vivo by gastrointestinal digests or in vitro by digestive or microbial proteolytic enzymes (Alhaj et al., 2016; Moslehishad et al., 2013; Salami et al., 2011; Alhaj et al., 2010; Salami et al., 2010; Korhonen & Pihlanto, 2003). Bioactive components are defined by Park (2009) as “compounds either naturally existing in food or ones formed and/or formulated during food processing that may have physiological and biochemical functions when consumed by humans”. Bioactive components derived from camel milk were found to be stable even after sterilization process and provide potential health benefits including ACE-inhibitory activity, antimicrobial, anticancer and antioxidant effect (Alhaj et al., 2016; Amr et al., 2015; Al-Saleh et al., 2014; Alhaj et al., 2011). In contrast, lactoferrin were completely inactivated after pasteurization (Claeys et al., 2014). Several studies have shown that bioactive components in camel milk could provide a number of health benefits (Abd El-Salam & El-Shibiny, 2013; Al-Juboori, 2013; Al haj & Al Kanhal, 2010; Shamsia, 2009).

**BIOACTIVITY OF CAMEL MILK PROTEINS**

Many food proteins including egg, corn, dairy products, wheat gluten, rice, fish and soybean proteins were found to encrypt bioactive peptides in their primary structures (Kitts & Weiler, 2003). Milk and dairy products have developed a high reputation as the most significant home of bioactivities because most of the well-known bioactive peptides are derived from milk proteins (Meisel, 2004). Furthermore, milk proteins, in addition to their high nutritional value, are available in the market in large amounts at moderate cost (Léonil et al., 2000). The protein content in bovine milk is 3.3% compared to 3.1% in camel milk which is made up of amino acids. The range of health claims is usually depending of the amino acid sequence of bioactive peptides. It has been reported that most of the milk protein derived bioactive peptides contain up to 23 amino acid residues per molecule (Otte et al., 2007; Korhonen & Pihlanto, 2003). Kitts & Weiler (2003) have defined bioactive peptides as “specific protein fragments
**Table 1. Mean values, standard deviation (SD), and range of variation of camel milk components**

<table>
<thead>
<tr>
<th>Components</th>
<th>Mean Value (SD)</th>
<th>Range of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids</td>
<td>11.9% (±1.5)</td>
<td>8.64 - 15.06%</td>
</tr>
<tr>
<td>Proteins</td>
<td>3.1% (±0.5)</td>
<td>2.15 - 4.90%</td>
</tr>
<tr>
<td>Casein/whey ratio</td>
<td>N/A</td>
<td>2.7 – 3.2</td>
</tr>
<tr>
<td>Casein (CN)</td>
<td>N/A</td>
<td>1.63-2.76% or 22.1 – 26 g/l*</td>
</tr>
<tr>
<td>β-CN</td>
<td>65%</td>
<td>N/A</td>
</tr>
<tr>
<td>αs1-CN</td>
<td>21%</td>
<td>N/A</td>
</tr>
<tr>
<td>κ-CN</td>
<td>3.47%</td>
<td>N/A</td>
</tr>
<tr>
<td>Whey proteins</td>
<td>N/A</td>
<td>0.63 - 0.80% or 5.9 - 8.1 g/l*</td>
</tr>
<tr>
<td>β-Lactoglobulin</td>
<td>absent*</td>
<td>absent</td>
</tr>
<tr>
<td>α-Lactalbumin</td>
<td>N/A</td>
<td>0.8 - 3.5 g/l*</td>
</tr>
<tr>
<td>Lactoferrin</td>
<td>N/A</td>
<td>0.02 - 7.28 g/l*</td>
</tr>
<tr>
<td>Lysozyme</td>
<td>N/A</td>
<td>(60 - 1350) x 10**</td>
</tr>
<tr>
<td>Immunoglobulins (Ig)</td>
<td>N/A</td>
<td>1.5 – 19.6 g/l*</td>
</tr>
<tr>
<td>NPN</td>
<td>0.68 g/l*</td>
<td>N/A</td>
</tr>
<tr>
<td>Lactose</td>
<td>4.4% (±0.7)</td>
<td>2.40 - 5.80%</td>
</tr>
<tr>
<td>Fat</td>
<td>3.5% (±1.0)</td>
<td>1.2 - 6.4%</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>34.5 mg / 100g</td>
<td>31.3 – 37.1 mg / 100 ml*</td>
</tr>
<tr>
<td>Conjugated linoleic acid (CLA)</td>
<td>0.4%*</td>
<td>N/A</td>
</tr>
<tr>
<td>Mineral</td>
<td>0.79% (±0.07)</td>
<td>0.60 - 0.90%</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>155.66 mg / 100 g (±37.88)</td>
<td>58 - 104 mg / 100 ml*</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>114.34 mg / 100 g (±13.35)</td>
<td>105 – 157 mg / 100 ml*</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>58.87 mg / 100 g (±16.22)</td>
<td>36 – 73 mg / 100 ml*</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>10.45 mg / 100 g (±1.78)</td>
<td>8 – 16 mg / 100 ml*</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>0.53 mg / 100 g (±0.08)</td>
<td>0.19 – 0.6 mg / 100 ml*</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>0.29 mg / 100 g (±0.09)</td>
<td>0.7 – 0.37 mg / 100 ml*</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>0.05 mg / 100 g (±0.03)</td>
<td>N/A</td>
</tr>
<tr>
<td>Vitamin</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>A</td>
<td>N/A</td>
<td>5 - 97µg / 100 ml*</td>
</tr>
<tr>
<td>D</td>
<td>N/A</td>
<td>0.3 – 1.6 µg / 100 ml*</td>
</tr>
<tr>
<td>E</td>
<td>N/A</td>
<td>21 – 150 µg / 100 ml*</td>
</tr>
<tr>
<td>C</td>
<td>N/A</td>
<td>2400 – 18,400 µg / 100 ml*</td>
</tr>
<tr>
<td>B1</td>
<td>N/A</td>
<td>10 – 60 µg / 100 ml*</td>
</tr>
<tr>
<td>B2</td>
<td>N/A</td>
<td>42 – 168 µg / 100 ml*</td>
</tr>
<tr>
<td>B3</td>
<td>N/A</td>
<td>400 – 770 µg / 100 ml*</td>
</tr>
<tr>
<td>B5</td>
<td>N/A</td>
<td>88 – 368 µg / 100 ml*</td>
</tr>
<tr>
<td>B6</td>
<td>N/A</td>
<td>50 – 55 µg / 100 ml*</td>
</tr>
<tr>
<td>B12</td>
<td>0.2 µg / 100 ml*</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Mean values, standard deviation (SD) and range of variation were adapted from Al haj & Al Kanhal, (2010); *adopted from Claeys et al. (2014). N/A stands not available.
that have a positive impact on body functions or conditions and may ultimately influence health”. Bioactive peptides in milk could be generated or enriched by adding starter or non-starter cultures due to their metabolic products required for their growth (Alhaj et al., 2007). Hence, milk cultured with combination of two or more type of strains exhibited a wider variety of functional components (Kuwabara et al., 1995). However, the addition of Lactobacillus helveticus or/and Lactobacillus acidophilus solely or in combination to camel milk was reported to release ACE-inhibitory peptides (Alhaj, 2012); antioxidant peptides (Al-Saleh et al., 2014); antimicrobial peptides (Alhaj, 2015). Likewise, the ACE-inhibitory, antimicrobial and antioxidant activities of camel whey proteins were found to improve after treatment with proteolytic enzymes such as trypsin, chymotrypsin and pepsin (Salami et al., 2011; 2010). The potential health claims and activities of camel milk will be discussed individually in the following sections.

**Angiotension Converting Enzyme (Ace) Inhibitory Activity**

ACE-inhibitory peptides are one of the most favored bioactive peptides applied in foodstuff formula to provide health benefits (Meisel & Bockelmann, 1999). The inhibition of angiotension converting enzyme using milk bioactive peptides is the most intensive studied mechanism internationally. As one of the major blood pressure regulators, the angiotensin-I-converting enzyme (ACE) was defined by Pan et al. (2005) as “an exopeptidase that cleaves dipeptides from the C-terminal ends of various peptide substrates and regulates the activity of several endogenous bioactive peptides” (P. 123). ACE acts on angiotensin-I in renin angiotensin system to hydrolyze the dipeptide; His-Leu from its C-terminal lead to producing a potent vasopressor angiotensin-II (Skeggs et al., 1956). Thus, a small decrease of 5-mm Hg in diastolic blood pressure (DBP) can reduce 15% of the risk of developing cardiovascular diseases (Meisel et al., 2006).

ACE-inhibitory peptides are present in the primary structure of various food proteins sources including milk protein (Meisel et al., 2006; Jang & Lee, 2005; Li et al., 2004). The level of ACE-inhibitory activity was found to essentially depend on the strain and degree of hydrolysis of protein (Alhaj et al., 2016), type of proteolytic enzyme and molecular weight (Salami et al., 2011). ACE-inhibitory bioactive peptides are produced using individual or combined cultures. The addition of L. rhamnosus to camel milk was recently studied and exhibited ACE-I activity (Moslehishad et al., 2013). Furthermore, Quan et al. (2008) identified ACE-inhibitory peptides (Ala-Ile-Pro-Pro-Lys-Lys-Asn-Gln-Asp) from Mongolia camel milk proteins using Lactobacillus helveticus 130B4. In another study, Alhaj et al. (2012) identified two ACE-inhibitory peptides corresponding to β-casein from water soluble permeates (WSP) of dromedary camel milk proteins using Lactobacillus helveticus 130B4. In another study, Alhaj et al. (2012) identified two ACE-inhibitory peptides corresponding to β-casein from water soluble permeates (WSP) of dromedary camel milk using Lactobacillus acidophilus solely. The identified ACE-inhibitory peptides were FQEPFPDPVR and VLPFQEPVPDPVRG. Donker et al. (2007) pointed out that most effective ACE-inhibitory peptides were originated from β-casein which represents about 65% of the total camel milk caseins (Kappeler et al., 2003). Furthermore, Seven ACE-inhibitory peptides were identified from WSP of dromedary camel milk incubated with Lactobacillus helveticus solely (Alhaj et al., 2012). Three peptides were released from sequences 1 (LSLSQF, SLSQF, or SQF) KVLVPQ, three peptides of the sequences 2 (TDLEN, DLEN, or LEN) LHLPLPL, and one peptide of the sequence 3 KVLVPQMQPYPQ. All identified ACE-inhibitory peptides were corresponding to β-casein of Camelus dromedarius milk and some contain at least one proline (P) residue at their C-terminal position. The C-terminal sequence of ACE-inhibitory peptides play important role in the binding to the ACE (López-Fandiño et al., 2006). Thus, amino acids having hydrophobic properties such as tryptophan (W), phenylalanine (F), tyrosine
(Y) and especially proline (P) are appeared to contribute substantially to inhibitory potency (López-Fandiño et al., 2006; Li et al., 2004).

**Antidiabetic Activity**

It has been early reported that camel milk has good results for stabilization of juvenile diabetes (Yagil, 1987). Camel milk supplementation can improve the glycemic control and reduce the doses of insulin for type 1 diabetes patients (Khan et al., 2012; Agrawal et al., 2011; Agrawal et al., 2003). In another study, the consumption of camel milk in India has lowered the prevalence of diabetes in the Raica community (Agrawal et al., 2007; Singh et al., 2008). In animal study, the supplementation of camel milk has reduced the level of blood glucose of diabetic albino rats (Baragob, 2015) and alloxan-induced diabetic dogs (Sboui et al., 2010) and the effect was depending on the amount of camel milk. The hypo-glycemic activity of camel milk is attributed to the presence of various components including the existence of high concentration of insulin like substances such as half-cystine, in addition to the regulatory and small size immunoglobulins functions of camel milk on β-cell (Breitling, 2002). Moreover, camel milk does not react to acid and form coagulation in human stomach; this could be another reason for hypoglycemic effect in camel milk (Agrawal et al., 2003).

**Antimicrobial Activity**

Camel milk was reported to contain a various antimicrobial agents including immunoglobulins, lactoperoxidase, lactoferrin, hydrogen peroxide and lysozyme (Al-Juboori et al., 2013). The amount of these agents in camel milk is greater than that reported for other mammalian antibacterial proteins (Kappeler et al., 1999). Xanthine oxidoreductase (XOR) protein is another antimicrobial compound in camel milk which could play an important antimicrobial defensive role in the neonatal gut (Harrison, 2006). Other antimicrobial compound was also isolated from camel milk but not detected in cow milk such as peptidoglycan recognition protein (PGRP) (Kappeler et al., 1999). Aforementioned components exist naturally in camel milk and have an antimicrobial effect against pathogenic strains including *Staphylococcus aureus*, *Listeria monocytogenes*, *Salmonella typhimurium* and *Escherichia coli* (Benkerroum et al., 2004; El-Agamy et al., 1992). Immunoglobulins are another natural protector in camel milk which functions against infections in the gut of newborns. These antimicrobial substances work with different inhibitory mechanisms, for instance, PGRP inactivate pathogenic strains by binding to peptidoglycan structures in the cell wall (Abd El-Salam & El-Shibiny, 2013). While, the inhibitory action of lactoferrin in camel milk against *S. typhimurium* is through binding iron and making it unavailable for its growth (Ochoa & Cleary, 2009). In contrast, the presence of lysozyme in camel milk was reported to prolong the gelation process of yoghurt due to the delay of yoghurt culture growth in camel milk (Jumah et al., 2001). It is evident that antimicrobial substances in camel milk lose their complete activity after heat treatment at 100 °C for 30 min (El-Agamy, 2000).

Camel milk encrypts antimicrobial peptides in their primary structure and could be released using digestive or microbial proteolytic enzymes. The activity of these antimicrobial peptides depends on strain, incubation time and peptides molecular weight. Additional factors were also found to enhance the antimicrobial effect including structural activity (Gobbetti et al., 2004). Whereas, the alteration of Asp (D) with Arg (R) and the addition of Lys (K) residues to the C-terminus of antimicrobial peptide were found to increase the bactericidal activity to Gram-negative bacteria (Pellegrini et al., 2001). Camel milk
inoculated with two added combined culture (*Lactobacillus acidophilus* and *Streptococcus thermophilus* or *Lactobacillus helveticus* and *Streptococcus thermophilus*) was found to exhibit varying degree of inhibition against *B. cereus*, *S. typhimurium* and *S. aureus* (Alhaj et al., 2016). This effect was mainly found to depend on culture, incubation time and antimicrobial peptide molecular weight. However, the antimicrobial inhibition activity of camel milk containing *L. helveticus* and *S. thermophilus* was higher than that noticed in camel milk containing *L. acidophilus* and *S. thermophilus*. This is attributed to the nature of proteolytic system of *L. helveticus* which result in more antimicrobial peptides formation.

**Antioxidant Activity**

There is strong evidence between diabetic, cardiovascular diseases, aging, cancer and the imbalance of free radical levels in the body (Sah et al., 2014; Shori, 2013). The formation of free radicals (superoxide anion radical and hydroxyl radical) is a normal result of aerobic organisms during respiration (Virtanen et al., 2007). An excess of free radicals formation could led to cause cellular or tissue injury by oxidizing cellular proteins, enzymes, membrane lipids and DNA (Sah et al., 2014). Under normal conditions, defense system shall prevent body from this damage using antioxidant enzymes and low molecular mass non-enzymatic antioxidant compounds (Virtanen et al., 2007). Antioxidants peptides could be derived from various food proteins including milk and dairy products; these peptides contain 5-16 amino acid residues and considered to be safe, low cost, healthy and easily absorbed in small intestine (Sarmadia & Ismail, 2010). According to the recent information by IFIC about 34% of consumers get enough food contain potential antioxidant effect (IFIC, 2013). The antioxidant activity of camel milk has been approved through a number of *in vitro* studies (Al-Saleh et al., 2014; Jrad et al., 2014; Shori, 2013; Salami et al., 2011) and *in vivo* studies (AL-Ayadhi & Elamin, 2013). Various methods based on radical scavenging inhibition (hydroxyl radical and DPPH) were adopted to determine the antioxidant activity of camel milk. The DPPH radical scavenging activity, total phenol compounds and reducing power of camel casein hydrolysate were reported to be greater than those of bovine casein hydrolysate and un-hydrolysed camel casein (Al-Saleh et al., 2014). These findings were supported by a recent study, which showed that free radical scavenging of camel casein and camel casein hydrolysate were higher than those found for camel milk whole protein and its hydrolysate (Jrad et al., 2014). This is attributed to the presence of camel β-casein (main casein in camel milk protein) which showed high antioxidant activity after hydrolysis with chymotrypsin (Salami et al., 2011). Moreover, the exposure of free radical scavenging amino acid residues such as phenylalanine, tryptophan, methionine, tyrosine and cysteine were found to increase the oxidative stability of casein hydrolysate (Moure et al., 2006).

**Anti-Cancer Activity**

According to the latest statistics of International Agency of Research on Cancer (IARC) in 2012 worldwide, the number of new cancer cases was 14.1 million, whereas the number of cancer deaths was 8.2 million. Moreover, people living with cancer (within 5 years of diagnosis) were 32.6 million (WHO, 2012). Colorectal cancer (CRC) is highly affected by the dietary and lifestyle factors thus could be substantially reduced by controlling the different risk factors, including the dietary ones. In general, the relation between dairy products and CRC are controversial (Gill & Rowland, 2003). There are some studies exhibited no significant effect associated between dairy products consumption and CRC. While, several studies suggested that increased consumption of dairy products including camel milk may el-
evate the risk of CRC (Amr et al., 2015, Korashy et al., 2012, Quita & Kurdi, 2010). Camel milk was reported to have superior chemo-preventive properties over cow milk, thus extensively consumed by cancer patients in the Middle East (Quita & Kurdi, 2010). The chemo-preventive effect of unfermented and fermented camel milk against different kind of cancers was studied using different cancer biomarkers. This effect is attributed to the bioactive components presence in milk and dairy products including conjugated linoleic acid, sphingolipids, calcium, lactoferrin, casein or addition of probiotic and prebiotic (Gill & Rowland, 2003). Camel milk has shown to inhibit the hepatic and breast cancers and to alleviate the hepatotoxicity induced by natural toxicants. Camel milk intubated to albino mice has significantly inhibited the micronucleated polychromatic erythrocytes (MnPCEs) in the bone marrow and increased the mitotic index induced by cisplatin chemotherapy (Quita & Kurdi, 2010). In another animal study, camel milk showed therapeutic effects to rats after aflatoxin B1 intoxication using amelioration of cancer blood biomarkers (Abdel Magjeed, 2005). In another research, camel milk has significantly inhibited cancer cells proliferation through the activation of caspase-3 mRNA and the induction of extrinsic and intrinsic apoptotic signaling pathways (Korashy et al., 2012). Recently, Amr et al. (2015) has studied the chemopreventive potential of camel milk compared to bovine milk, however both milks exhibited chemopreventive potential on Fischer rates against preneoplastic lesions as expressed by ACF in the early stages of colon carcinogenesis.

**Hypoallergenicity Activity**

Some infants are born allergic to various food components including milk and even soy milk. Approximately 70% of sensation to food allergens is being disappeared at the age of six (Kulig et al., 1999). On the other hand, up to 23% of children are sensitized without showing symptoms (Kirjanvainen, 2003). There is no doubt; mothers’ milk is the ideal nutrition for newborn infants during the early months of life. Although, infants in many cases need to complete their necessary nutrition with some alternative formulae such as soy milk, goat milk or extensively hydrolyzed milk protein formulae (El-Agamy, 2007). Approximately 10-20% of children showed allergenicity to bovine milk are also expressed sensation to soy derivatives (El-Agamay et al., 2009, Maldonado et al., 1998, Businco et al., 1992). Researchers have recently proposed camel milk proteins as alternative to children allergic to bovine milk. It is evident that high incidence of allergenicity in bovine milk is related to the high percentage of αs-casein (Taylor, 1986) and β-lactoglobulin (El-Agmay, 2007). In contrast, camel milk is hypo-allergic similar to mothers’ milk due to the high percentage of β-casein, low percentage of αs-casein (El-Agamay et al., 2009), similarity of immunoglobulins (Shabo et al., 2005) and deficiency of β-lactoglobulin (Kappeler, 1998). Accordingly, camel milk is expected to cause a little hypersensitivity reactions (El-Agamay et al., 2009). Nevertheless, no immunological similarity was found between camel and cow milk using ELISA technique (El-Agamay et al., 2009). Therefore, camel milk could be proposed as a new protein source for children allergic to bovine milk.

**BIOACTIVITY OF CAMEL MILK OLIGOSACCHARIDE**

Like other milk sources, lactose is the dominant saccharide in camel milk and consist 4.4% of total milk composition (Al haj & Al Kanhal, 2010). Other substantial quantities of saccharides including neutral
and acidic oligosaccharides, glucose, fructose, and glucosamine were also found in camel milk (Fox & McSweeney, 1998). Oligosaccharides are carbohydrates with a degree of polymerization contain a small number of saccharide units (between 3 and 14), most of these have lactose residue and some N-acetyl groups (Walstra et al., 2008). The potential health claims of milk oligosaccharides and their proposed mechanisms are discussed by Boehm & Stahl (2007) and Kunz and Rudloff (2006). These claims are summarized as follows: modulate the intestinal flora, affect different gastrointestinal activities, effect on mineral absorption, anti-adhesion effect against pathogens, enhance the immune system, and enhance the growth of *Bifidobacterium bifidum*. In particular attention, 3’-GL oligosaccharide which is considered as a prebiotic component was detected in camel milk (Alhaj et al., 2013). This oligosaccharide could be used as a food additive in infant formula (Urashima et al., 2009).

The number and concentration of identified oligosaccharides in human milk is much higher than that reported for domestic mammalian animals including camel milk (Alhaj et al., 2013; Fukuda et al., 2010; Urashima et al., 1997). Researchers (Boehm & Stahl, 2003) recorded eighty-seven oligosaccharides in human milk compared to thirteen and seven characterized oligosaccharides in Bactrian camel milk /colostrum (Fukuda et al., 2010), and in Dromedary camel milk (Alhaj et al., 2013), respectively. Furthermore, the concentration of oligosaccharides in camel and bovine milk compared to human milk was found to decrease during lactation (Finke, 2000; Martin et al., 2001; Fukuda, et al., 2010). On the other hand, significant homology and heterogeneity differences were reported in the oligosaccharides structure between human and camel milk (Alhaj et al., 2013; Fukuda et al., 2010; Mehra & Kelly, 2006). Two oligosaccharides; Sialyl-3’-galactosyllactose and sialyllacto-N-novopentaose-a were not detected in human milk/colostrum but detected in camel milk. In contrast, 3’-GL, LNNH, 3’-SL, 6’-SL and MSLNnH oligosaccharides are both detected in dromedary camel and human milk (Alhaj et al., 2013). The following oligosaccharides, Sialyllacto-N-novopentaose-a, LNNH and MFLNnH, which contain Gal(β1–4)GlcNAc(N-acetyllactosamine), are categorized as Type II oligosaccharides and only found in Dromedary and Bactrian camel milk (Alhaj et al., 2013). Accordingly, the presence or absence of Type I oligosaccharide that contain Gal(β1–3)GlcNAc (lacto-N-biose I) is expected to be the main significant contrast between human and camel or bovine milk oligosaccharide (Fukuda et al., 2010).

**BIOACTIVITY OF CAMEL CONJUGATED LINOLEIC ACID (CLA)**

For many years the concept of eating dairy products was likely associated for being harmful to health due to the presence of saturated fat and cholesterol. This concept was misleading and often inaccurate because not all fatty acids or saturated fatty acids have the same biological effects. Researchers concluded that fatty acid within a whole diet context has to be considered individually to clarify the link between health and diet (Parodi, 2009; Lock et al., 2008). Bauman et al. (2006) highlighted a number of bioactive components in milk fat (e.g. essential fatty acids including conjugated linoleic acid, vaccenic acid, butyric acid, sphingolipids, 13-methyltetradecanoic acid, stearic acid, ether lipids, omega-3 fatty acids and vitamins A, D). Conjugated linoleic acid (CLA) is the most important bioactive component in milk fat due to its inhibitory effect on cancer, immune function, inflammation, diabetes and atherosclerosis (Gnädig et al., 2003). The concentration of CLA in camel milk fat is 4.56 mg/g which is greater than that reported for cow milk (Al-khdier et al., 2014; Cardak et al., 2003). This concentration was found to increase in camel milk through addition of some starter cultures including *Bifidobacterium angulatum*,...
Bifidobacterium longum subsp. Infantis and Lactobacillus delbrueckii subsp. bulgaricus (Al-khdier et al., 2014). More extensive research is needed to investigate the functional properties of CLA in camel milk fat. The current information is highly important but not enough to warrant a strong conclusion.

BIOACTIVITY OF D AND L AMINO ACID IN CAMEL MILK

Among the proteinaceous foodstuffs, milk is of major importance not only for infants but also for children and adults. This is attributed to its high nutritional value in terms of essential AAs and contents of calcium. Although L-amino acids are the major structure blocks of peptides and proteins of all living organisms; however, the corresponding stereoisomers (enantiomers) of L-amino acids is called D-amino acids which occur in low amounts in milk as well as most tissues of all mammals. In recent years, positive health effects of some D-amino acids established and some were used as pharmaceutical drugs including D-Asp stimulates testosterone synthesis, increases human sperm count and mobility, and is implicated in human pre-ovulatory follicular fluid (D’Aniello et al., 2007, Topo et al., 2009). The Mg-salt of DL-Asp is also used as magnesium supplement and protection against heart diseases, D-Ser is used to treat the schizophrenia and D-Phe for treatment of Parkinson’s disease (Stenberg et al., 2002).

In the last decades, many studies have analyzed the presence of D-amino acids in many processed foods. These studies assumed that D-amino acids are released in dairy products, fermented beverages and other products matured by the presence of some active bacteria (Brueckner & Hausch, 1990). However, raw milk is usually contaminated with microorganisms, such as anaerobic bacteria of the genera Bacterioides, Ruminococcus and Butyrivibrio. The low amount of free D-amino acids found in milk is significant and expected to be due to the result of the bacterial digestion and autolysis (Brückner & Fujii, 2010). The addition of cultures to camel milk of various dairy products has significantly enhanced the D-amino acid content. For example, the addition of three starter cultures (Lactobacillus acidophilus and Streptococcus thermophilus; Lactobacillus helveticus and Streptococcus thermophilus; and Lactobacillus bulgaricus and Streptococcus thermophilus) have relatively increased the concentration of D-Ala, D-Val, D-Orn, D-Lys and D-Arg in fermented camel milk (Alhaj, 2015). The amino acid content was varied depending on starter culture and fermentation process. The current available information on D-amino acid content in camel milk is scarce in the literature; further work is needed to highlight the importance of D-amino acid in camel milk.

CONCLUSION AND FUTURE RESEARCH

Camel milk is a good source of bioactive components for the people living in the arid and urban areas. The current available information is highly important but extensive research is required to support the present potential health claims and their proposed mechanisms. Functional products based on camel milk source are required in the commercial market due to increasing demand in recent years. These products have to be clinically proven, scientifically evident supported and exhibit no side effect after consumption. Consumers have to be given more awareness about the healthfulness and importance of camel milk.
REFERENCES


Functional Properties of Camel Milk


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Functional Properties of Camel Milk


