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REVIEW ARTICLE
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Camel Milk Yield and Composition and its Adjuvant Potential Impacts on Health of Consumers: A Review

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ABSTRACT

Dromedaries can be integrated efficiently into an extensive and intensive management milk production systems for producing milk. Camel milk has specific nutritional values that alleviate certain diseases. The camel milk can be produced under harsh and intensive management conditions. Camel milk was given to human and experimental animal species under normal and dysfunction conditions as hyperglycemic, hyperlipidemic and hepatitis. The articles concerning management conditions of producing camel milk and its specific nutritive values were used for writing the manuscript and they were collected from google scholar, ScienceDirect, PubMed databases. The results indicated that camels species were significantly produced milk either under harsh or intensive management conditions. The constituents of chemical camel milk were differed among species, stage of lactation, and management systems. The nutritional values of camel milk were explored as antihyperglycemic, antihyperlipidemic, anti-cancer, and others. The possible biological candidates in camel milk include lactoglobulins, lactoferrin, and lysozyme. It could be concluded that camel milk has a potential nutritional therapy, where it is effected on blood glucose values, liver and kidney functions.

Key words: Camel milk, Chemical, Diabetes, Kidney, Liver, Oxidative stress.

The world population is projected to reach 9.7 billion by the year 2050 and 10.4 billion by the year 2100 due to higher life expectancy and decreasing mortality. Water and food security are among the priorities of the 21st century that cannot be achieved without intensive and sustainable agriculture production. Therefore, providing food for humans is an urgent need through intensification and expansion of livestock and crop production, which started some decades ago (Gilbert *et al.*, 2021). Camels are the most important animal species adapted to survive in the harsh environmental conditions in addition to their abilities to produce milk, meat and offspring (Kakar *et al.*, 2008; Mohammed and Mahmoud, 2011; Djenane and Aider, 2024; Mohammed and Alshaibani, 2024).

The number of camels is approximately estimated to be more than 35 million heads at world level (FAO 2013; Tharwat *et al.,* 2023). The roles of camels in the livestock economy of countries is highly variable according to different factors including species, management systems and environmental factors (Faye, 2020; Chamekh *et al.*, 2020) (Table 1). There is a continuous increase in the total number of dairy camels and this is resulted in a noticeable increase in camel milk production (El-Hanafy *et al*., 2023).

It has been estimated that about 2.12 million tons of camel milk was produced from 5.25 million of she-camels in 2010 (Ramadan and Inoue-Murayama, 2017). Camel milk represents an important protein source for people living in the arid regions of the world as nomadic communities (Arain *et al.,* 2024). Several studies in the last two decades were explored the changes in camel milk production and composition in addition to their potential effects for body health and therapeutic of certain diseases in experimental animals and humans (Faye, 2020; Chamekh *et al*., 2020; Liu *et al.,* 2023; Djenane and Aider, 2024). Therefore, the aims of this review article were designed to provide a comprehensive overview concerning the changes in milk production and composition due to management system, the nutritional value of camel milk and its potential impacts on body health and therapeutic of certain diseases (Fig 1).

The experimental procedure was approved by the ethical committee of King Faisal University [Ref. No. KFU-REC-2024-AUG-EA050]. The articles concerning anatomy of the dromedary mammary gland, factors affecting camel milk yield and composition, camel milk composition and nutritional value, camel milk as a potential therapeutic for hyperglycemia, hyperlipidemia and others were collected form SciencDirect, PubMed and Google Scholar databases. Therefore, our targets are to highlight key aspects of camel

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milk production and composition and it is effect on body health and therapeutic of diseases.

Functional anatomy of the dromedary mammary gland

The udder of the dromedaries is divided longitudinally through the *Sulcus intermammarius* into right and left halves. Each half is divided into front and back quarters (Fig 2). The shape of udders and teats differs between camels, where is influenced by species, age and lactational stage. The udder form was mostly globular udder and the teat form was the funnel one (Müller *et al.,* 2024). Each quarter of the camel udder consists of two distinct glands (Fowler, 1998). The gland consists of teat cistern and extensive branching ducts, which were divided into large, medium, and small milk ducts. The hindquarters produce about (56.4%) of udder milk compared to (43.6%) of the front quarters. Ohari and Joshi (1961) showed that the milk composition is similar between fore and hindquarters. The knowledge of anatomical dromedary udder structures may be useful for selection of dairy dromedaries and application of automatic or machine milking. Atigui *et al.* (2021) explored the correlation between udder characteristics and milk flow rates of dairy camels. They stated that daily milk yield and milk flow rate were highly correlated with udder depth and teat diameter. Therefore, recognition of factors that effect on camel machine milking ability for camels has decisive implications for adjusting the machine design and management.

Factors affecting camel milk yield and composition

Camel milk yield and composition monitoring throughout lactation is a target for exploiting camel potential and understanding factors of variation. Dairy camels were categorized into three groups, low, medium and high according to their milk yield and lactational length ranges from 6 to 18 months (Alhadrami and Faye, 2016). Hand milking and longer calving interval retard progress in improving camel milk yield and quality. Camel milk yield from intensive management system has shown promising result (Chamekh *et al*., 2020). Although the peak of lactation tends to decline more steeply in camels compared to dairy cattle, camel provide milk to people living in the arid and semi-arid area better than sheep, goats and cows (Alhadrami, 2002). The effects of genetic and non-genetic factors on milk yield and compositions have been explored in several studies (Table1).

Camel milk nutritional values

Composition of camel milk is similar to composition of goat and cattle milk (Yasmin *et al*., 2020). Camel milk has opaque white colour and sweet taste but it can be salty sometimes due to feeding strategies (Alhadrami 2002). Camel milk has high nutritional value and health benefit (Nikkah 2011; Ganzorig *et al*., 2020). Camel milk includes nutrients including proteins, fats, lactose, vitamins, minerals, etc (El-Hanafy *et al*., 2023). Our unpublished data of camel milk composition of Majahem breed under intensive management system during the first month of lactation indicated 3.35% proteins, 4.11% fats, 4.88% lactose, 9.08% solid none fat, 1.0262 density, 0.58% minerals (Mohammed and Alshibani unpublished).

As mentioned earlier, camel milk production and composition is influenced by different factors including breeds, age, parity, management systems and environmental conditions. After consuming, digestion and absorption of camel milk produces in the small intestine peptides, which aid in treatments of diabetes and hypertension, and delay liver and kidney damages. Moreover, the various camel milk biological activities may be related to its exosomes (Liu *et al*., 2023). Camel milk contains lactoglobulins, lactoferrin, and lysozymes higher than cattle milk. In addition, camel milk has been indicated to have hypoallergenicity properties compared to cattle milk. Besides, camel milk has similar nutritional composition and curative properties compared to human milk (Oselu *et al.,* 2022).

Camel milk as a potent superfood for potential therapeutic of diseases

Camel milk, because of its unique properties, has been used to treat some diseases in certain regions of Africa and Asia since ancient times and researchers have recently

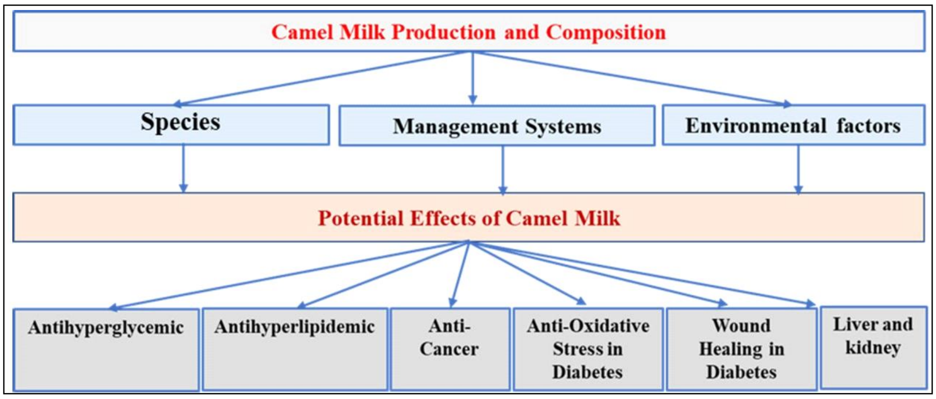

Fig 1: Camel milk production and its effect on body functions and therapeutic of diseases.

begun to explore these disease-curing claims using camel milk and camel milk products (Kanha, 2010). Evidences from laboratory and medical studies indicate that camel milk and/or urine are effectives in treating many diseases such as diabetes, cancer, viral hepatitis, autism, food allergies and a group of other bacterial, viral and parasitic infections (Alavi *et al*., 2017; Oselu *et al.,* 2022; Shakeel *et al*., 2022).

Antihyperglycemic effects of camel milk

Diabetes is a worldwide metabolic disease and is currently a topic of great interests, which necessitated effective alternative treatments (Pandey *et al*., 2011; Mirmiran *et al*., 2017). Diabetes is a disease recognized by high blood sugar that results from failure of pancreas to secrete the adequate amount of insulin hormone (Type I) or inability of target cells including muscle, liver and fat cells to respond to hormone insulin action (Type II) (Tuomilehto 2013; Zheng *et al*., 2018).

Camel milk is suggested to be a suitable hypoglycemic factor in patients with diabetes and experimental animals (AlKurd *et al.,* 2022; Mohammadabadi and Jain, 2024). Clinical studies for patients with type I diabetes have shown that consuming camel milk lowers blood glucose value and reduces the amount of insulin required for treatment by 30-35% (Mirmiran *et al*., 2017; Mohammadabadi and Jain 2024). Agrawal *et al.,* (2007) found zero prevalence of diabetes in north-west Rajasthan community consuming camel milk. It appears that camel milk contains insulin-like proteins that enhance health of diabetic patients. The mechanism of action is suggested in the following scheme (Fig 3).

Mucosal surfaces are the pathway for proteins and peptides (Garcia-Castillo *et al*., 2018). However, when insulin is given orally, it encounters mucosal barriers and is digested by digestive enzyme before entering blood stream. As a unique property of camel milk, insulin-like proteins are protected in the stomach and are efficiently absorbed into the bloodstream until they reach the target location in the body's cells. This is because camel milk does not curdle in an acidic condition (Agrawal *et al*., 2004). Since there was no differences in the composition of the camel insulin-like proteins and their digestibility's compared to proteins of other dairy sources, it is possible that the camel insulin-like proteins are protected in the stomach by nanoparticle as lipid vesicles to reach the target cells (Malik *et al.*, 2012). Camel milk contains about 52 μU/ml of insulin-like proteins compared to 16.32 μU/ml for cattle milk, which mimics the interaction of insulin with its receptors. It has a high content of zinc (Konuspayeva *et al.*, 2022) and has a key role in the secretory activity of insulin from pancreatic β-cells (Anwar *et al.*, 2022). Beg *et al.* (1986) found that the amino acid sequences in camel milk proteins are rich in a half cystine compound, which has a surface similar to peptides of the insulin family.

Some investigators propose that camel insulin-like proteins have the ability to resist proteolytic digestion, which makes its absorption into the blood faster than those from other dairy milk sources. It has been shown that raw camel milk has the ability to reduce blood sugar levels by about 55.0% compared to cow's milk in diabetic rats (Kamal *et al.*, 2007). Fresh or raw camel milk showed a higher ability to lower blood glucose levels than pasteurized camel milk during a four-week period of treatment (Agrawal *et al.*, 2005a,b). Similar results were obtained in dogs and rabbits (El-Said *et al.*, 2010). In addition, the insulin level in serum was higher in diabetic rabbits treated with camel milk compared to those not treated with camel milk or insulin treatment during a period of four weeks. In rabbits with diabetes, treatment with camel milk has a much higher ability to lower blood glucose levels than biosynthetic insulin.

Agrwal *et al.* (2003) found that camel milk reduced blood glucose levels when given as an adjuvant treatment for type I diabetics for three months. At the end of the three months, it was found that there was a significant decrease

Fig 2: Morphology of udder she-camel.

Table 1: Camel milk production and composition factors.

Factors	References
Breeds	Nagy *et al.* 2017; El-Hanafy *et al.*, 2023
Parity	Ahmad *et al.* 2012; Aljumaah *et al.* 2012
Lactation stage	Konuspayeva *et al.* 2010; Musaad *et al.* 2013; Ayadi *et al.*, 2018
Feeding regime	El-Hatmi *et al.* 2004; Al-Saiady *et al.* 2012
Season	Haddadin *et al.* 2008; Nagy *et al.* 2017
Management system	Ayadi *et al.,* 2018; Chamekh *et al.*, 2020
Geographical region	Konuspayeva *et al.* 2009, 2010; Konuspayeva 2020a,b
Year and sex	Nagy *et al.* 2017

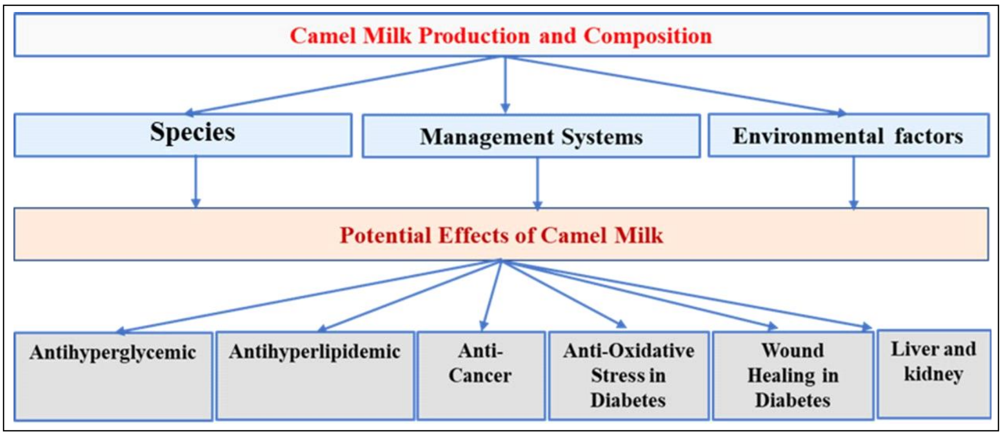

Fig 3: Antihyperglycemic effects of insulin-like proteins of camel milk.

in the doses of insulin required to control blood sugar, in addition to a significant increase in the level of hemoglobin type. Therefore, giving type I diabetics a treatment that includes camel milk in addition to insulin is better than giving either one alone. Finally, researchers believe that camel milk can be safely consumed by individuals without diabetes or healthy people (Cheikh Ismail *et al.,* 2022; Profeta *et al.,* 2022).

Antihyperlipidemic effect of camel milk

Diabetes is accompanied with changes in blood lipids, triglycerides and lipoprotein (Hirano 2018; Yang *et al.,* 2022). It results in vascular and heart complications (Li *et al.*, 2023; Zakir *et al.*, 2023). Thus, lowering cholesterol values using diet or medical treatment appears to reduce risk of heart disease (Hooper *et al.*, 2020). Low-density lipoprotein-C in the blood passes to the liver through specific receptors (Pirahanchi *et al.,* 2023; Feingold, 2024). An increase in the blood plasma levels of LDL in diabetics leads to a defect in the LDL-C receptors, resulting in a defect in their production or function (Li *et al.,* 2023). LDL-C is a protective substance for the body by reversing cholesterol transport, preventing the oxidation of LDL-C and neutralizing the atherogenic effects of oxidized LDL-C (Ahotupa, 2024). There is an association between the level of very low-density lipoprotein-C and HDL-C. A significant increase in both LDL-C and VLDL-C may lead to a significant decrease in HDL-C levels. In addition, low levels of HDL-C may also occur due to decreased activity of the enzyme lecithin cholesterol acyltransferase (Al-Numair, 2010).

Several studies have shown that camel milk can help lower lipid profiles in diabetic patients (Khalid *et al.,* 2023). Camel milk reduced total cholesterol values in dogs induced with diabetes using Alloxan drug compared to cow's milk (Sboui *et al.*, 2010). Moreover, camel milk also improved fat properties even after five weeks of stopping to drink camel milk (Sboui *et al.*, 2010). AL-Numair (2010) stated that camel milk is able to reduce blood lipids. In this study, diabetic rats treated with camel milk for 45 days had a significant reduction in the levels of total cholesterol, triglycerides, free fatty acids (FFA's), phospholipids, low-density lipoproteins and lipoproteins. Very low-density lipoprotein in plasma and tissues (kidney, liver, heart) increased while high-density lipoprotein decreased. Similar results were obtained in other study of diabetic rabbits treated with camel milk (El-Said *et al.*, 2010).

Mohamad *et al.* (2009) demonstrated the effectiveness of camel milk as a superfood treatment for patients with type I diabetes, as total cholesterol and triglycerides decreased to 25% and 37%, respectively, after consuming camel milk for 16 weeks, while no significant change occurred in HDL, LDL and VLDL values. Patients with type I diabetes treated with insulin, camel milk, or both were showed the efficiency of both insulin and camel milk in improving lipid profiles compared to insulin or camel milk alone (El-Sayed *et al.*, 2011). Collectively, it could be concluded that the health-promoting effect of camel milk supports its role in treating dyslipidaemia.

Liver and kidney functions through camel milk

Prevalence of liver disease and increased levels of liver enzymes are common in individuals with diabetes. Evaluating the levels of liver enzymes in the blood (AST and ALT) reflects the release of liver enzymes from its cells into the blood as a sign of injury (Lala *et al.*, 2023; Mohammed *et al.,* 2024a,b,c). The beneficial effects of camel milk on human health extend to liver and kidney functions. A significant improvement was found in the liver enzymes of diabetic rats that were treated with camel milk (Khan *et al.*, 2012; Alharbi *et al.*, 2022).

Microvascular kidney dysfunction in diabetic patients is widely considered one of the risks of diabetes (Jha *et al.,* 2024). It has been known that albuminuria is a sign of kidney dysfunction (Pasternak *et al.,* 2022). The urine albumin level within 24 hours ranges from 30-300 mg per urine sample (Prasad *et al.,* 2023). It has been found that camel milk has a potential role in the urine albumin level of patients with type I diabetes (Agrwal *et al.*, 2009). A significant decrease in urine albumin was found for patients with type I diabetes when camel milk was added to their diet for six months. Moreover, kidney function through uric acid, urea and creatine levels were returned to normal values in diabetic rats given camel milk (Hamad *et al.*, 2011; Badr 2013). Collectively, liver and kidney functions were improved upon consuming camel milk either in normal or diabetic conditions.

CONCLUSION

Camel milk can be significantly produced either under harsh or intensive management conditions. The chemical constituents of camel milk were differed among species, stage of lactation and management systems. The consumption of camel milk due to its nutritional values as superfood provides benefits to healthy people and patients with antihyperglycemic, antihyperlipidemic, anti-cancer, liver and kidney malfunctions and others. Further studies are required for improvement camel milk production and quality and the constituents involved in therapy of diseases.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

Not applicable

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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