Camel milk consumption as a natural preventive strategy against dysmetabolic disorders and implications for dairy industry development in Somalia

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Abstract

Camels are divided into dromedaries and Bactrian camels. The dromedary camel is mainly concentrated in the Horn of Africa, the Middle East, and North Africa, while the Bactrian breed is mostly domesticated in Asia. In these areas, the camel is the best livestock to rely on because it can withstand and survive during droughts and climatic hardships. According to recent statistics from the Food and Agriculture Organization (FAO), the global camel population is estimated at around 19 million, with approximately 15 million found in Africa. Somalia holds the largest national herd, with about 7.5 million camels. Camels produce 5-10 liters of milk daily for a more extended period (9 months) than any other livestock under the same harsh environmental conditions. Camel milk is regarded as more nutritious and healthier than cow's milk due to its rich content of beneficial minerals and vitamins, including calcium and phosphorus, which are the primary mineral constituents present in camel milk. These minerals are essential for bone growth and children's development. Camel milk is also rich in vitamin C, containing up to 30 times more than cow's milk, as well as zinc and iron. Regular consumption of camel milk provides a natural way to protect against hepatic steatosis induced by a high-fat diet. It also effectively controls hyperglycemia by reducing fasting blood sugar and improving insulin resistance in patients with type 1 and type 2 diabetes. Some studies have also shown that camel milk is rich in insulin, which is not destroyed in the gastrointestinal tract, making it a potential treatment for type 1 and type 2 diabetes. Moreover, recent studies have revealed that camel milk contains exosomes enriched with microRNAs (miRNAs), which can be absorbed through the diet. Once internalized, these miRNAs can modulate gene expression at the mRNA level in humans, including genes involved in adipogenesis, lipid metabolism, and other functions essential to human health.

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Introduction

The camel, belonging to the *Camelidae* family within the *Artiodactyla* order, includes two distinct species: the two-humped Bactrian camel (*Camelus bactrianus*) and the one-humped Arabian or dromedary camel (*Camelus dromedarius*). Camels hold significant socio-economic value in many arid and semi-arid regions worldwide, and their milk is a vital part of human diets in these areas;[1] camel milk remains an essential nutritional source for pastoralist communities across many African and Asian countries.[2]

Camels produce larger quantities of high-quality milk over longer periods than other livestock species, even in environments characterized by extreme temperatures, prolonged drought, and scarce pasture – conditions that can rightly be described as hostile.[3]

Camels are multipurpose animals; they are used for milk, meat, and hides, as well as for transportation, entertainment, celebration, and competition, including racing and beauty shows. As a result, the Somali people consider the camel as the most dependable and esteemed animal. This cultural significance is captured in the Somali proverb: "*Aakhiro nimaan Geel Lahayn Lama ammaanayn*" (*A man without a camel is not praised in the afterlife*). Camel milk has been regarded as a potential nutritional and therapeutic food source across various arid and semi-arid regions. This milk composition is similar to cow's milk, with a high concentration of medium-chain fatty acids in the fat, low lactose levels, and abundant vitamin C and iron.

Consuming camel milk is associated with anti-diabetic, anti-cancer, antihypertensive, and other health-benefiting properties.[4] For the last quarter century, much scientific research about the health and nutritional benefits of camel milk has been published. Many of these studies have associated concrete health and nutritional benefits with the consumption of camel milk. Particular attention was given to the health benefits of camel milk for several chronic metabolic diseases like diabetes and non-alcoholic fatty liver disease (NAFLD).

A previous study found that camel milk has lower cholesterol and higher levels of minerals (sodium, potassium, iron, copper, zinc, and magnesium) and vitamin C than other ruminant milks.[5] Moreover, camel milk contains various fatty acids, enzymes, and protective proteins, and it has potential therapeutic effects, such as antibacterial, antiviral, antidiabetic, anti-aging, and anticarcinogenic. The medicinal properties of camel milk are attributed to its protective proteins. Furthermore, Korish *et al.* found that the regular consumption of camel milk provides natural protection against NAFLD induced by a high-fat diet.[6]

More recently, small sequences (18-22 nucleotides, microRNAs [miRNAs]) of the non-coding genome present in plants, animals, and humans have been discovered and characterized. miRNAs are a subclass of regulatory, non-coding RNAs that properly adjust gene expression at a post-transcriptional level by affecting mRNA translation and stability. Up to 30% of human genes could potentially be regulated by miRNAs. In this context, the miRNAs involved in adipogenesis are also part of the epigenetic mechanisms that regulate gene expression at a post-transcriptional level, even in healthy obese individuals. The ability of miRNAs to share the same targets while having diverse functions increases the complexity of biological networks. In particular, 18 miRNAs may promote adipogenesis by repressing Wnt signaling, including miRNA-210, miRNA-148a, miRNA-194, and miRNA-322. In contrast, 29 miRNAs negatively affect adipogenesis by activating Wnt signaling in 3T3-L1 cells, including miRNA-344, miRNA-27, and miRNA-181.

This review paper aims to summarize the scientific literature on the multidimensional health and nutritional benefits of camel milk, particularly its potential benefits for people with metabolic diseases, including obesity, diabetes, and hepatic steatosis. A preliminary analysis of the economics of milk production and transformation in the Mogadishu area is also carried out.

Milk protein

Camel milk exhibits a protein profile closely resembling that of human milk, rendering it a potentially suitable nutritional source for newborns. Notably, it lacks β-lactoglobulin, a protein commonly found in ruminant milk and a known allergen. This absence positions camel milk as a viable alternative to human milk, particularly for infants with allergies or intolerances to bovine milk proteins. Another crucial anti-allergenic factor is that camel milk contains immunoglobulins similar to those in human milk, which are known to reduce children's allergic reactions and strengthen their future response to foods.[7]

Milk mineral components

The main minerals in milk are calcium, phosphorus, magnesium, sodium, potassium, and chlorides, as described by Konuspayeva *et al.*[8] Those minerals are very important for bone growth and the proper development of newborns.

Consumption of camel milk and its products is also presumed to be associated with antidiabetic, anti-cancerous, anti-hypertensive, and many other health-benefiting properties, as outlined by Al-Juboori *et al.*[9] Manganese and iron levels in camel milk are markedly higher – ranging from 7- to 20-fold for manganese and 4- to 10-fold for iron – compared to human milk, bovine milk, and infant formula, as reported by Al-Awadi *et al.*[10] Therefore, it can be concluded that camel milk is nutritious and meets human dietary requirements. It is also suitable for consumption by babies.[11]

Milk vitamins

Generally, camel milk is rich in essential vitamins for a healthy body. It's worth noting that camel milk contains a high concentration of vitamin C. It contains 30 times more vitamin C than cow's milk and 6 times more than human milk. This is highly important in desert areas, where fruits and vegetables are scarce. Therefore, camel milk is often the only source of vitamin C in the diet of inhabitants of those regions, as reported by Haddadin *et al.*[12]

miRNA in camel milk

Over the past decade, extensive research has focused on the specific roles of exosomes and their cargos in intercellular communication during adipogenesis in human obesity. miRNAs, as key epigenomic regulators, play an important role in many biological processes associated with obesity. During adipogenesis, miRNAs accelerate or inhibit adipocyte differentiation, thereby regulating not only fat cell development but also fat cell numbers. miRNA profiles during adipocyte differentiation and during the permanent obesity phase are quite different. Some miRNAs function as negative regulators of adipocyte differentiation, while others accelerate adipogenesis. Co-transportation of miRNAs that activate or inhibit any of the signaling pathways of adipocyte differentiation within the same exosome elicits a complex effect on adipogenesis.

In the exosomes of camel milk, non-coding small RNAs were sequenced and identified by next-generation sequencing technology, and the miRNA fraction was analyzed by bioinformatics. A total of 2,659 miRNAs were identified, including 2,458 known and 201 new. Among the known miRNAs, miR-148a and let-7i had the highest expression levels. The results of gene ontology enrichment analysis indicated that the target genes of camel milk exosome miRNAs were involved in multicellular organismal, catabolic, and other biological processes. They play a role in the extracellular region, in the cytoskeleton and other cell components, and in protein binding, but also have structural molecule activity and other molecular functions. According to the results of the Kyoto Encyclopedia of Genes and Genomes pathway enrichment analysis, the target genes of camel milk exosome miRNAs are involved in Alzheimer's disease, NAFLD, *Staphylococcus aureus* infection, and other metabolic pathways, such as obesity, hypercholesterolemia, diabetes, and hypertension. The beneficial effect of camel milk in various pathologic conditions may be closely related to the regulatory function of exosomal miRNAs on target genes involved in metabolic diseases.

Therapeutic properties of camel milk

Consumption of camel milk and its products is presumed to be associated with antidiabetic effects, as noted by Al-Juboori *et al*.[9] The fat content of camel milk consists of unsaturated fatty acids (beneficial fats) and volatile fatty acids, mainly linoleic acid, which make the milk more digestible and more cardiovascular friendly. El-Hatmi *et al.* reported that camel milk contains higher levels of protective proteins, including lysozyme, lactoferrin (which also functions as an innate defence), and immunoglobulins, compared to cow and buffalo milk.[13] These proteins demonstrate antibacterial, antiviral, antifungal, and antiparasitic activities, in addition to immunological properties, growth-promoting effects, and anti-tumor functions. Furthermore, camel milk has been recognized for its additional medicinal properties, including the treatment of tuberculosis, ulcers, respiratory ailments, and hepatitis.[14]

Many researchers have agreed that camel milk differs from other ruminant milk in having lower cholesterol and sugar levels.[12] Recently, many studies have reported that camel milk can have therapeutic characteristics against hypertension and diabetes.[15]

Gizachew *et al.* reported that insulin in camel milk exhibits unique properties that facilitate easier absorption into the bloodstream compared to insulin from other sources and that it contributes to the proteolysis of insulin resistance.[11] Although human, cow, and goat milk contain insulin, it is degraded in the acidic environment of the stomach. This does not occur with camel milk, which does not react to acid, and no coagulum is formed. Camel insulin is encapsulated in nanoparticles (lipid vesicles) that make its passage through the stomach and entry into the circulation possible. As described by Gizachew *et al*., other components of camel milk also make it anti-diabetic.[11] Furthermore, clinical studies have shown that daily consumption of camel milk lowers blood glucose levels in patients with type 1 diabetes and reduces insulin requirements.[16]

Camel milk transformation and preliminary insights for an agro-economic business plan in Somalia

This scientific review provides a strong foundation for promoting the increased use of camel milk in Somalia, not only as a strategy to combat the persistent issue of childhood malnutrition, but also as a preventative measure against chronic metabolic diseases associated with growing urbanization. Indeed, lifestyle changes, dietary changes, and lack of physical activity, with advancing age, become a significant factor in the development of chronic diseases linked to an altered metabolism: hypertension, hypercholesterolemia, and diabetes. However, marketing products from faraway production areas poses challenges, as maintaining a long-distance cold chain is neither easy to implement nor commercially viable. Regarding long-term preservation methods at high temperatures, the resistance of camel milk proteins to UHT treatment (135-150°C for 2-3 seconds) has recently been demonstrated. In 2016, suitable methods were developed for this milk, enabling it to be marketed in a ready-to-use liquid form that can be distributed even at considerable distances from the production site.

To promote a 20-30% increase in the production, processing, and consumption of camel milk in the Mediterranean basin, the CAMELMILK project was launched. This Italian initiative was selected under the PRIMA 2018 call for proposals in the Food and Food Supply Chain section. The project spans 36 months, starting from April 1, 2019, and is funded with a budget of 2 million euros.

The project is coordinated by Spain, through the Institute of Agri-food Research and Technology (IRTA, *Institut de Recerca i Tecnologia Agroalimentàries*), and includes the Italian research unit Food and Agriculture Requirements (FARE). In total, fourteen research units from eight countries are involved: Algeria, Germany, Croatia, France, Italy, Morocco, Spain, and Turkey.

In the Mogadishu area, the "Camel Milk Supply Chain" project is currently underway, coordinated by Prof. Mohamed Jimale. The project aims to identify small- and medium-scale camel breeders, enhance milk production, and ensure the rapid or refrigerated transport of the milk to a sterilization and bottling facility, from where it is distributed to various retail outlets.

The business plan is being developed in collaboration with Sordi Srl (sordi.com), a company with over 150 years of experience in cow's milk processing plants, and more recently active in camel milk processing in Dubai.

Camel farming has been on the rise in recent years. In Somalia, camel milk is consumed primarily fresh or left to acidify naturally and consumed within 3-4 days. Unfortunately, this practice can pose health risks to the population. From an industrial standpoint, camel milk can achieve an extended shelf life and be marketed outside the cold chain through high-temperature heat treatment. Once treated, the milk can be packaged in glass or high-density polyethylene (HDPE) bottles and sterilized in an autoclave, with a shelf life of up to 6 months at room temperature. While cardboard packaging must be imported, local production of glass and HDPE bottles is anticipated. Maintaining a cold chain is considered cost-prohibitive, and converting the milk into powder is not a viable alternative due to the high financial and energy requirements. Sterilization processing appears to be the most feasible option; recent plants built by Sordi Srl, which already present satisfactory management levels, are located in the North African basin: Dubai and Saudi Arabia. An industrial plant with high safety and sanitation standards requires an incoming volume of camel milk ranging from 6,000 to 10,000 liters per day to demonstrate economic sustainability.

To produce the quantity of milk required for an industrial facility as envisioned above, a single facility, even one distributed across a suitably integrated supply chain of multiple livestock and agronomic facilities, should have the following preliminary characteristics: i) a dedicated herd of approximately 1,200 to 2,000 lactating camels, each producing an average of 5 liters of milk per day; ii) a livestock capacity with an annual rotation of at least 10% of newly born female camels selected for future lactation; iii) the installation of 4 to 5 wells to support irrigation needs, livestock water consumption, and general farm operations; iv) access to 8,000-10,000 hectares of land, both for the proper management of livestock movements and animal welfare, and for the necessary crops, in addition to the associated industrial and farm facilities; v) a strategic location with reliable access to major road and/or rail networks to facilitate transportation and logistics.

These initial parameters must be further analyzed through a comprehensive local-area development plan that includes agronomic, industrial, and market aspects.

Conclusions

Camel milk differs from other ruminant milk by containing low cholesterol, low sugar levels, high mineral content (including

sodium, potassium, iron, copper, zinc, and magnesium), and elevated vitamin C levels, as well as insulin (150 U/mL) and insulin-like proteins.[17,18]

Although human, cow, and goat milk contain insulin, it is degraded in the stomach's acidic environment, forming a coagulum. On the contrary, the insulin of camel milk is contained within micelles and thus protected from digestion and proteolysis in the upper gastrointestinal tract; it is encapsulated in nanoparticles that facilitate its absorption and easy passing to the bloodstream. It is also plausible that the antioxidant action of camel milk helps prevent metabolic syndrome, including hyperglycemia, hyperlipidemia, and insulin resistance.[18]

The study conducted by Agrawal *et al.*[19] reported the beneficial effects of camel milk consumption on type 1 diabetes, as it significantly reduced the insulin doses required to maintain long-term glycemic control. The study also demonstrated that the insulin concentration in camel milk is higher than that in cow milk. Similarly, a recent study also proved that camel milk is a rich source of insulin.[6] Furthermore, it has been shown that camel milk can serve as an additive to insulin therapy, as it appears to be safe and effective in enhancing long-term glycemic control and also contributes to reducing insulin needs in type 1 diabetes patients.[19] Other studies have shown that the daily consumption of camel milk decreases the blood glucose level of patients with type 1 diabetes and insulin requirement by 30%. Additionally, daily consumption of camel milk may reduce the risk of developing diabetes complications, such as high cholesterol levels, liver and kidney diseases, and delayed wound healing.[18] Its therapeutic efficacy may be due to the lack of coagulum formation of camel milk in acidic media of the digestive tract.[20]

Somalia is considered the heartland of the world's dromedary population, and the majority of Somalis live in rural areas where camel herding plays a vital role in their livelihood. For many, camels represent not only a source of prestige but also a key source of food and income. Given this deep cultural and economic connection, it is highly advisable to plan and implement comprehensive research into the potential health benefits of camel milk, particularly in relation to metabolic diseases such as diabetes, liver and kidney disorders, and NAFLD.

With an estimated 6.5% of the Somali population affected by diabetes mellitus, further studies are urgently needed to explore the impact of camel milk on glucose metabolism, insulin resistance, and other metabolic conditions.

In this context, efforts are currently underway in Somalia to develop the camel milk sector through improved dairy production, processing, and marketing, aiming to enhance both health outcomes and economic opportunities for the population.

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