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Review on camel milk and its products

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Dedications

*I dedicate my diploma, the fruit of my efforts, the culmination of my studies and my joy that I have waited for throughout my life, to the one who opened the path of knowledge and was the first support for me. to achieve my ambitions, to the one who has been my rightful refuge in this journey, to the one who showered me with love and tenderness, and made me feel happy and secure, to the one who only allows me not to pray day and night, to whom I can not find words to express its value to my dear **mother**.*

*may God preserve and protect her, and to the light that illuminated my path and the lamp whose light in my heart never fades, to the one on whose hand I was raised and who taught me values and principles, to the one whose name is inseparable from his name, and who is present in the spirit of my heart and never absent, to my dear **father**, may God protect him. Truly no dedication can express my attachment, my love and my affection*

*To my **grand mothers***

*To all my **sisters***

*To all my **friends***

To all those I love and who love me without exception

To all the people who have crossed my path and who have contributed to

that I become a better person.

ARIDJ



Dedications

*With enormous pleasure, an open heart and
immense joy‘*

That I dedicate this work:

*To my support in life , to the most precious thing
in the universe , my dear father **Laid***

*Everything i am today my mother helped me
become ,dedicate my graduation to her spirit*

*To whom I wish a bright future full of success, my
only brother**Massoud***

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:**Oumayma,Amel,Khouloud, Amani***

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beautiful gift from God:**Nouran***

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girlfriends: **Youssra ,Zahra ,Ikram, Safa, Aridj***

*To my extended family, my sisters
husbands, my grandmother, my aunts.*

IKHLAS



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Abstract

Camel milk is a popular dairy product that is consumed in many parts of the world. It is known as a super food due to its many health benefits which are attributed to its unique composition and properties. In this general review, we will explore some of the main characteristics of camel milk, including its composition, the lactic acid bacteria present in camel milk and its products, as these types of bacteria play a vital role in the fermentation process. where, camel milk and its products have gained widespread attention for their potential health benefits and help manage certain diseases like diabetes Among the unique properties of camel milk insulin is its resistance to breakdown even in the acidic environment of the stomach, unlike human beings, Additionally, camel milk is believed to have a lower lactose content than cow milk, making it a better option for individuals with lactose intolerance and it is good for intestinal health, antibacterial and antiviral, and the lactoferrin acts as a multifunctional protein, including strong pathological effects and the ability to inhibit cancer cell proliferation. We will also look at some of the challenges the products (yogurt and cheese) are facing. By the end of this review, readers will have a better understanding of the potential benefits and drawbacks of incorporating camel milk into their diet, as well as the different ways it can be used.

Résumé

Le lait de chamelle est un produit laitier populaire qui est consommé dans de nombreuses régions du monde. Il est connu comme un super aliment en raison de ses nombreux avantages pour la santé qui sont attribués à sa composition et à ses propriétés uniques. Dans cette revue générale, nous explorerons certaines des principales caractéristiques du lait de chamelle, notamment sa composition, les bactéries lactiques présentes dans le lait de chamelle et ses produits, car ces types de bactéries jouent un rôle vital dans le processus de fermentation. où, le lait de chamelle et ses produits ont suscité une large attention pour leurs bienfaits potentiels pour la santé et aident à gérer certaines maladies comme le diabète Parmi les propriétés uniques de l'insuline du lait de chamelle se trouve sa résistance à la dégradation même dans l'environnement acide de l'estomac, contrairement aux êtres humains, , on pense que le lait de chamelle a une teneur en lactose inférieure à celle du lait de vache, ce qui en fait une meilleure option pour les personnes intolérantes au lactose et il est bon pour la santé intestinale, antibactérien et antiviral, et la lactoferrine agit comme une protéine multifonctionnelle, y compris de forts effets pathologiques et la capacité d'inhiber la prolifération des cellules cancéreuses. Nous examinerons également certains des défis auxquels les produits (yaourt et fromage) sont confrontés. À la fin de cette revue, les lecteurs auront une meilleure compréhension des avantages et des inconvénients potentiels de l'incorporation du lait de chamelle dans leur alimentation, ainsi que des différentes façons dont il peut être utilisé.

ملخص

حليب الإبل هو أحد منتجات الألبان الشهيرة التي يتم استهلاكها في أجزاء كثيرة من العالم. يُعرف باسم الغذاء الفائق نظرًا لفوائده الصحية العديدة التي تُعزى إلى تركيبته الفريدة وخصائصه. في هذه المراجعة العامة ، سوف نستكشف بعض الخصائص الرئيسية لحليب الإبل ، بما في ذلك تركيبته ، وبكتيريا حمض اللاكتيك الموجودة في حليب الإبل ومنتجاته ، حيث تلعب هذه الأنواع من البكتيريا دورًا حيويًا في عملية التخمير. حيث حظي حليب الإبل ومنتجاته باهتمام واسع النطاق لفوائدها الصحية المحتملة والمساعدة في إدارة بعض الأمراض مثل مرض السكري ومن بين الخصائص الفريدة لأنسولين حليب الإبل مقاومته للانحيار حتى في البيئة الحمضية للمعدة ، على عكس البشر ، بالإضافة إلى ذلك. يُعتقد أن حليب الإبل يحتوي على نسبة أقل من اللاكتوز من حليب البقر ، مما يجعله خيارًا أفضل للأفراد الذين يعانون من عدم تحمل اللاكتوز وهو مفيد لصحة الأمعاء ، ومضاد للبكتيريا والفيروسات ، ويعمل اللاكتوفيرين كبروتين متعدد الوظائف ، بما في ذلك التأثيرات المرضية القوية والقدرة على منع تكاثر الخلايا السرطانية. سننظر أيضًا في بعض التحديات التي تواجهها المنتجات (الزبادي والجبن). بحلول نهاية هذه المراجعة ، سيكون لدى القراء فهم أفضل للفوائد والعيوب المحتملة لدمج حليب الإبل في نظامهم الغذائي ، بالإضافة إلى الطرق المختلفة التي يمكن استخدامها بها.



Introduction

Camel milk is generally opaque white and low in carotene. Camel milk has a sweet and sharp taste, but sometimes can also be salty. Most of the camel milk is consumed fresh or in fermented forms. The health benefits attributed to this milk are important drivers for the development of a camel milk sector worldwide (**Alhadrami et al., 2022**).

Camel milk differs from other ruminant milk as it contains low cholesterol, low sugar, high minerals, high vitamin C and higher protective proteins like lactoferrin, lactoperoxidase, Immunoglobulins and lysozyme (**Abdullahi, 2019**).

Camel milk provides a common source of nutrition but also a potential rich source of beneficial, pathogenic, and potentially pathogenic microorganisms. Lactic acid bacteria fermentation helps mitigate the impact of poor handling and storage conditions by enhancing shelf life and food safety. Traditionally-fermented sour milk products are culturally accepted and widely distributed worldwide with product-specific microbiota responsible for aroma, flavor, and texture. Knowledge of microbiota and predominant, technologically important microorganisms associated with camel milk is critical in developing products with enhanced quality and safety, as well as sustainable interventions for these products, including camel milk specific starter culture development(**Kaindi et al., 2020**).

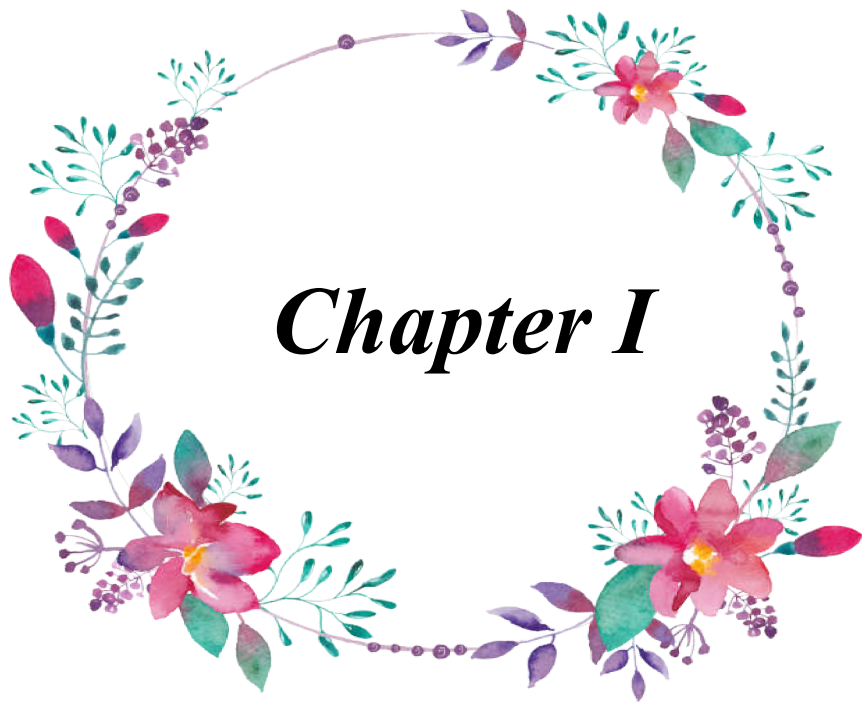
Epidemiological surveys have indicated that people who are consuming camel milk have low prevalence of diabetes (**Patel et al., 2022**). Although some attempts have been made to produce dairy products from camel milk, processing of camel milk is generally considered to be difficult and the quality of the final products made from camel milk do not correspond to their cow milk counterparts. The protein composition and colloidal structure of camel milk differs from cow milk. It is characterized by absence of β -lactoglobulin, low κ -casein content, high proportion of β -casein, larger casein micelles and smaller fat globules. These differences lead to the difficulty of making dairy products from camel milk using the same technologies as for cow milk. Some of the challenges of camel milk impaired rennetability, formation of weak and fragile curd during coagulation, longer fermentation time, and low thermal stability of the milk during drying. Despite these difficulties, it has now become possible to produce a range of commercial and traditional dairy products from camel milk (**Seifu, 2023**).

Camel milk has been recognized for its extraordinary medicinal properties. It is known to have a therapeutic potential against many diseases including diabetes (**Hussain et al., 2021; Arain et al., 2022; Khan et al., 2022**), cancer and skin diseases(**Oselu et al., 2022; Patel et al., 2022**).

We noticed a big difference in the results of research studies, as many researchers made reviews about camel milk, such as **Konuspayeva et al., (2022)** worked on minerals, **Seifu. (2023)** on camel milk products, **Patel et al., (2022)** on comprehensive on the properties of camel milk and milk products, **Fufa et al., (2020)**on quality and therapeutic aspect of camel milk. Where we tried to collect the largest number of new references related to camel milk and its products in the period from **2019** to **2023**.

This review, we tried to make our contribution to a better knowledge of camel milk and its products by collecting 112 references and we discussed four chapters, namely:

- 1-Composition of camel milk
- 2-Lactic bacteria of camel milk and its products
- 3-Milk products of camel milk
- 4-Benefets of camel milk and its products



Chapter I

Camel milk occupies an important place in the human diet because of its balanced benefits, composition of essential nutrients. Although camel milk, also known as desert gold, shares some similarities with human milk, it differs from it in both physical and chemical ways. The nutritional and physiological benefits of camel milk have increased interest in it over the past few decades. In this chapter we will talk about camel milk and its components in terms of quantity and quality, and the factors affecting it.

I.1 General properties of camel milk

Camel milk has an opaque white colour due to the lack of β -carotene and riboflavin and sometimes tastes salty due to camels feeding on halophilic plants (**Bhateshwar *et al.*, 2021; Abd El-Aziz *et al.*, 2022**). According to **Bouras *et al.* (2022)** all components of camel milk decreased from December to February and there was a trend of growth from June to August. Also, food supply plays an important role and can explain the special richness of camel milk. Several studies have shown that camel milk retains its quality for 12 days at 2°C, while cow milk retains its properties for no more than 2 days at the same temperature (**Hammam *et al.*, 2019**). Moreover, camel milk has a high boiling point compared to cow milk at 7°C. The boiling point is affected by the water content of the milk, the substances dissolved in it, and the pressure under which the milk is boiled. In addition, The freezing point of camel milk ranges between -0.57°C-0.61 °C (**Learoussy *et al.*, 2020; Fufa, 2021**). According to **Seifu. (2022)** the composition of camel milk is affected by animal nutrition, age of camel, lactation stage, parity and season.

I.2 Composition and constituents of camel milk

We'll concentrate on the most important components of camel milk in this section, including its proteins, lipids, vitamins, carbohydrates, minerals, and water.

I.2.1 Proteins

Milk proteins are a diverse range of substances with unique compositions and capabilities. According to studies, camel milk typically contains between 3% and 3.90% protein (**Abdullahi, 2019**). According to the findings, camel milk has 32.6 g/L of proteins, compared to 32.4 g/L and 30.2 g/L of proteins in cow and goat milk, respectively (**Bouhaddaoui *et al.*, 2019**). While in another study, total protein had an average A value (in g/100 ml) of $3.1 \pm 0.5\%$, ranging from 2.15% to 4.90% (**Seifu, 2022**). And the concentration of milk proteins varies according to the season, the stage of lactation and the number of births, and these results are consistent with (**Bouras *et al.*, 2022**). Camel milk protein is classified into two main groups:

I.2.1.1 Casein

Casein is a major part of the protein in has 1.63% to 2.76% of casein protein that constitutes 87% of total milk protein. There are 4 main casein their proportion is diverse κ and β , α_{S1} , α_{S2} , α fractions casein: and polymorphism of these proteins was demonstrated in most of the animal species. The human casein does not contain the α_{S1} -fraction, which is the predominant factor causing milk α protein allergy. However; it is rich in fraction β -casein proteins precipitate at pH 4.6 , and on a dry-weight basis, casein micelles contain 94% caseins and 6% minerals, primarily some magnesium and citrate, and trace amounts of other species (**Abdullahi, 2019**).

The major casein in camel milk is β -casein (65% of total casein), it is higher than that of cow milk (36%). β -casein is more easily hydrolyzed than α -casein. On the other hand, camel milk has lower α_{S1} -casein (21%), in comparison to bovine α_{S1} -casein (38%) it has been reported that camel milk caseins have higher molecular masses in contrast to bovine caseins, as β -casein and α -casein which were found to be 28.6 kDa and 35 kDa, respectively whilst, in bovine it is 24 kDa for β -casein and 22–25 kDa for α -casein the κ -casein in camel milk is only 3.47% of total casein, whereas cow milk has 13% of κ -casein. Studies have shown that κ -casein is relatively harder to be detected because of its low concentrations in the camel milk (**Swelum et al., 2021**).

I.2.1.2 whey protein

Whey proteins of camel milk which account for 20–25% of the total proteins also vary from whey proteins of and 0.63% to 0.80% of milk (**Behrouz et al., 2022; Chhasatiya et al., 2022; Seifu, 2022; Vincenzetti et al., 2022**), while contains the majority of the two major whey proteins, α -lactalbumin, and the deficient one β -lactoglobulin. Serum albumin, lactoferrin, immunoglobulins, and peptidoglycan recognition protein are among the other whey proteins found in camel milk. Camel milk proteins contain strong antibacterial, antiviral and antifungal substances and the immune globulins (**Behrouz et al., 2022; Chhasatiya et al., 2022; Vincenzetti et al., 2022**).

According to **Seifu. (2023)** the major difference between camel milk and cow milk whey proteins is in their β -lactoglobulin content. β -lactoglobulin, which is the major whey protein of bovine milk, is absent in camel milk. Lack of β -lactoglobulin in camel milk affects the rheological properties of yoghurt made from camel milk, which often has weak gel structure and thin consistency. During thermal processing of milk at or above 80 °C, β -lactoglobulin denatures and

this reaction increases the water binding capacity of the whey proteins and thus responsible for the improved texture.

I.2.2 lipids

I.2.2.1 fat

Fat is the major substance defining milk energetic value and makes a major contribution to the nutritional properties of milk, as well as to its technological suitability. Lipids build 30% of the membrane and can be further broken down into the following groups: phospholipids (25%), cerebrosides (3%), and cholesterol (2%). The remaining 70% of the membrane consists of proteins (Hassen, 2020).

Fat content of camel milk is between 1.2% and 5.4% with an average of 3.29% and can be reduced to 1.1% in the milk of thirsty camels which depends upon level of nutrition, stage of lactation, breed and season (Rahim et al., 2020; Benmeziene, 2021; Singh et al., 2021; Swelum et al., 2021; Abd El-Aziz et al., 2022; Arain et al., 2022). It has been shown that the camel milk fat is has special characters that when left standing and distributed as minor globules throughout the milk. The fat globules are very small 1.2–4.2 microns in diameter. The appearance of fat globule has thicker membrane than in that of other types of milk. As a consequence of camel milk fat is appears to be bound to the protein, it is challenging to remove fat by means of usual technique of churning sour milk (Zakir et al., 2021; Abd El-Aziz et al., 2022).

Camel milk fat was reported to act as an emulsifier more than human or cow milk because it contains almost 1% of its total lipids as phospholipids. Furthermore, the amount of plasmalogen and sphingomyelin were similar in camel and human milk (Bakry et al., 2021). Alhadrami et al. (2022) mentioned that phospholipids are a small, but important, fraction of the lipids of milk and are found mainly in the milk fat globule membrane. Camel milk contains more phospholipids than cow and goat milk.

I.2.2.2 fatty acid

About 99% of milk fat is a mixture of fatty acids (triglycerides) of varying chain length from 4 to 20 carbon atoms. The fatty acids are divided according to the linkage of the carbon atoms into saturated and unsaturated fatty acids. In saturated fatty acids the carbon atoms are linked in chain by single bonds, in unsaturated fatty acids by one or more double bonds (Fufa et al., 2020).

According to **Lajnaf. (2020)** previous works reported that the fat of camel milk contains a higher amount of fatty acids with long chain (C₁₄-C₂₂) and lower quantity of short chain fatty acids when compared to cow milk. Furthermore, it contains more unsaturated fatty acids than cow milk, especially the essential fatty acids. In addition to that the composition of fatty acids in milk fat is highly complex since they are derived from rumen microbial metabolism, body storage, and dietary fatty acids. Fatty acids are typically categorized into three groups depending on their saturation level, Saturated Fatty Acids, Monounsaturated Fatty Acids and Polyunsaturated Fatty Acids, which comprise *n-6* (omega-6) Polyunsaturated Fatty Acids and *n-3* (omega-3) Polyunsaturated Fatty Acids (**Bakry et al., 2021**).

I.2.2.3 Cholesterol

Cholesterol is present in the milk fat globule membrane and it accounts for 95% of the sterols of milk fat. Small Fat Globules are characterized by a larger surface area of milk fat globule membrane per fat unit. Therefore, a bigger share of Small Fat Globules is connected with a relatively higher concentration of cholesterol in milk (**Hassen, 2020**). **Lajnaf. (2020)** claims that however, the average cholesterol content in camel milk fat fraction (~34.5mg/100g) is higher than cholesterol content of cow milk (~25.6mg/100g) as well as the cholesterol of other mammalian species.

I.2.3 Carbohydrate

According to **Hassen. (2020)** the major carbohydrate fraction in camel milk is lactose sugar. The nature of vegetation eaten by the camels in desert areas could be a significant factor for extensive variation in lactose contents. Camels generally like to take halophilic plants like salosa, Acacia and Artiplex to fulfill their physiological necessities of salts. **Abd El-Aziz et al., (2022)** reported that the lactose content of dromedary camel milk ranges between 2.4–5.8%, but it ranges between 4.0–5.0% in cow milk. However, lactose content in human milk is the highest (6.8–7.5%) when compared to both camel milk and cow milk. The other significant carbohydrates of human milk are the oligosaccharides, ranging between 0.1–1.0% in normal milk and 1.5–2.3% in colostrums. Fucosylated constitutes approximately 35–50%, sialylated 12–4% and nonfucosylated 42–55% of oligosaccharides in human milk (**table 02**).

I.2.4 Mineral

Bouras *et al.* (2022); Konuspayeva *et al.*, (2022) stated similar results where they found that camel milk contains several types of minerals, and the mineral content of camel milk (7.16 ± 1.66 g/l) is higher compared to cow milk (5.15 ± 2.07 g/l). According to their value and availability, the minerals in camel milk are divided into two categories:

I.2.4.1 Macrominerals

The main minerals in milk are calcium, phosphorus, magnesium, sodium, potassium, and chlorides. These minerals are generally electrically charged, and it is possible to distinguish the cations (positively charged as Ca^{++} , Mg^{++} , Na^+ , K^+) from the anions (Cl^- , PO_4^{3-}). Some elements (Ca^{++} , Mg^{++} , PO_4^{3-}) are associated with milk proteins, contributing notably to form casein micelles (colloidal particles) involved in cheese processing. Some minerals are diffusible and contribute for example to the salty taste. Although their global quantity in camel milk rarely overpasses 1 g/L (**Konuspayeva *et al.*, 2022**) (table 01).

Table (01): The content of camel milk of the main minerals and their value

| Minerals | Mean value in camel milk | Lowest value | Highest value | Camel milk | Cow milk |
|-------------------|--------------------------|--------------|---------------|------------------|------------------|
| Calcium | 0.3 to 2.57 g/L | August | January | 0.70 ± 0.09 | 0.04 ± 0.66 |
| Phosphorus | 0.34 to 1.00g/L | August | December | 0.031 ± 0.81 | 0.072 ± 0.95 |
| Magnesium | 0.045 and 0.2mg/L | \ | \ | 14 ± 67 | 2.4 ± 134.2 |
| Sodium | 0.16 to 0.59 g/L | March | August | 79 ± 428 | 2.4 ± 134.2 |
| Potassium | 2 g/L | January | September | ± 281563.2 | 1470 ± 15.5 |

I.2.4.2 Microminerals

It is generally stated that camel milk contains also high quantities of trace elements, especially iron and zinc. Copper content in camel milk ranges from 30 to 800 $\mu\text{g}/100$ ml, did observe significant change in the milk copper content. From one region to another. However, camel milk is the poorest regarding copper content zinc content in milk is highly variable according to authors 30–1,200 $\mu\text{g}/100$ mL. Zinc content changed according to lactation stage with a significant trend to decrease throughout the lactation, and according to the farming systems. Iron is one of the most important trace elements for the young mammals as their requirements are high before

weaning, and milk of the human is the only source of iron. Camel milk contains more iron than other milk, the assertion that camel milk is particularly rich in iron and recommended for anemic people. Camel milk also contains magnesium and sodium (Konuspayeva *et al.*, 2022).

I.2.5 Vitamins

Milk is an excellent source of vitamins, both fat- and water-soluble ones, and camel milk is particularly high in vitamins D, E, A, C, and A (Hassen, 2020).

Vitamin C is one of the vitamins identified in camel milk and is present in extremely high concentrations. According to Zakir *et al.* (2021) the vitamin C content of camel milk is depend on lactation progresses or synthetic activity in the mammary tissues during early phase of lactation that declined as lactation advanced. The vitamin C levels are ranges amid 5.7 to 9.8-mg/l, this high level of vitamin C is relatively one-and-a-half that of human milk and three times than that of cow milk. The camel colostrums have a higher level of vitamin A, B₂ and E than mature camel milk. Other authors reported that camel milk contains 30 times more vitamin C than cow milk does, and 6 times more than human milk. This is highly important in desert areas, where fruits and vegetables are scarce. So, camel milk is frequently the only option (Hassen, 2020; Benmeziane, 2021).

Abd El-Aziz *et al.* (2022) declared that, camel milk contains higher B₃ levels than cow milk, but lower levels of B₁, B₂, B₅, B₁₂, and -tocopherol. When compared to milk from other livestock, camel milk has a lower pH due to the high vitamin C (ascorbic acid) content, which stabilizes it and allows it to last longer without cream formation (Zakir *et al.*, 2021; Oselu *et al.*, 2022).

Table(02):chemical composition of camel milk form some countries

| COUNTRY | Water(%) | Protein(%) | Fat(%) | Lac(%) | Ash(%) | References |
|----------------------|----------|------------|-----------|-----------|-----------|------------------------------------|
| Kenya | 86-88 | 3,0-3,9 | 2,9-5,4 | 3,3 | 0,6-0,9 | Abdullahi, 2019 |
| Ethiopia | 86-88 | 3,0-3,9 | 2,9-5,4 | 3,3 | 0,6-0,9 | Hassen, 2020 |
| Sudan | 88,5 | 2.5 - 4.5 | 2,9-5,5 | 2,9-5,8 | 86.3 | Muhammed Abdul et al., 2020 |
| Marocoo | 89,58 | 2,55 | 2,72 | 4,37 | 0,87 | Benmeziane,2021 |
| India | 86-88 | 3,0-3,9 | 2,9-5,4 | 3,3 | 0,6-0,9 | Hassani et al., 2022 |
| Botswana | 89,0 | 3,1 | 3,2 | 4,3 | 0,8 | Seifu, 2022 |
| Arab Emirates | / | 2,15–4,90 | 2,30–6,40 | 2,40–5,80 | 0,60–0,99 | Mohamed et al., 2022 |

I.2.6 Water

Water is the most important factor in camel milk. Unlike other animals, the water content of camel milk increases during dehydration. With water freely accessible the water content of the milk is 86%, but when water is restricted the water content of milk rises to 91%. The reasons for the increment of the water content of milk of dehydrated camel are ADH secretion is elevated in the dehydrated camel, a decrease in the fat content (**Abdullahi, 2019**). The variation in water content of camel milk was observed in numerous research findings, where the water content of camel milk fluctuates from 84% to 90%. Camels produce diluted milk in hot weather when water is scarce (**Eyassu, 2022**).

I.3 Main differences between camel milk and cow milk

It is important that we conclude this chapter by adding the most important differences that explain the difference in the composition of camel milk and cow milk, which is considered table milk, and these differences are highlighted in the following figure (**Figure 01**).

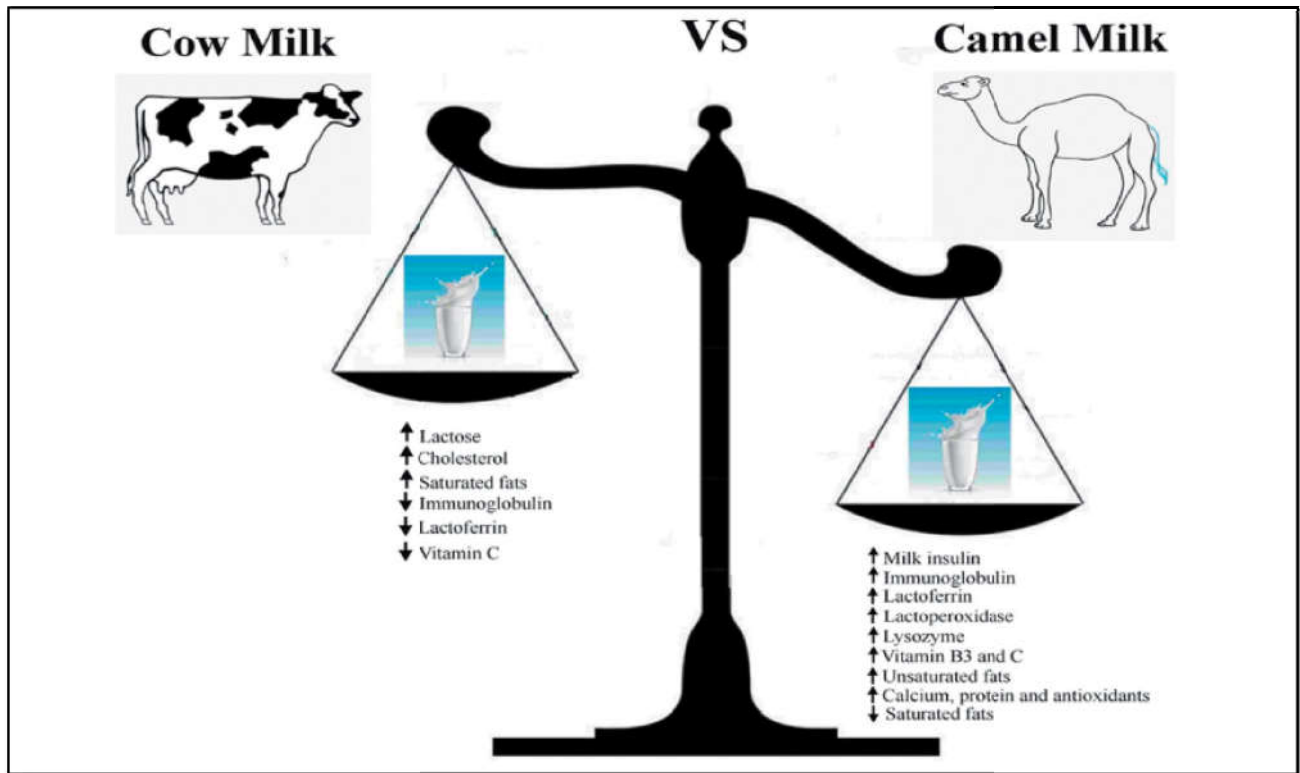
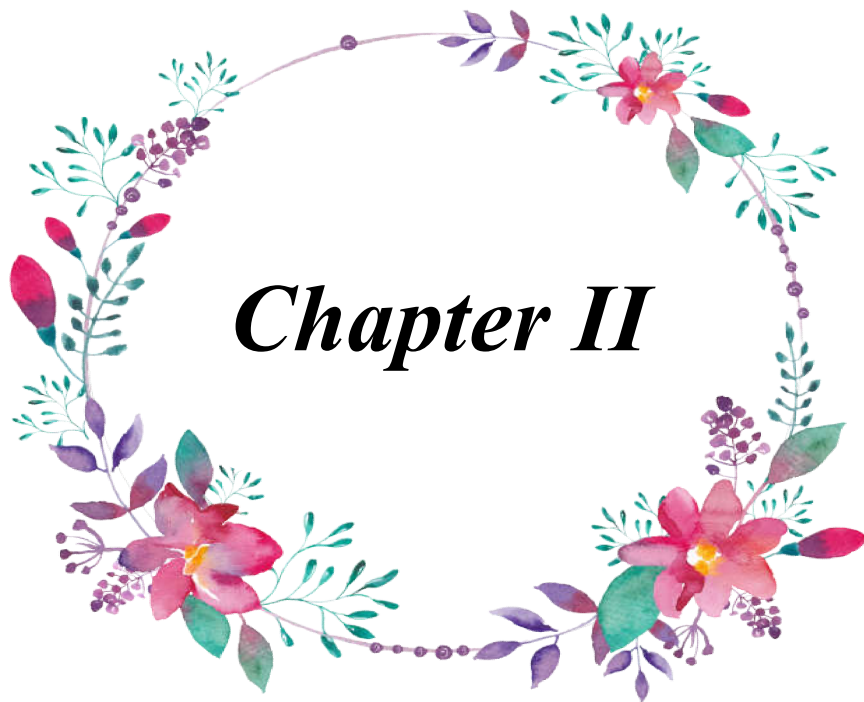


Figure (01): The schematic illustration shows the major differences between camel and cow milk (Arain *et al.*, 2022).



Chapter II

Camel milk is a medium that allows the growth of many diverse bacterial species that have important technological properties, health-promoting effects, and the ability to produce several antimicrobials that can be used as food preservatives. Many attempts have been made earlier to identify lactic acid bacteria from camel milk and its products. In this chapter, we will discuss lactic acid bacteria in camel milk and its products.

II.1. Lactic Acid Bacteria

Lactic acid bacteria are a diverse group of non-motile, Gram-positive, microaerophilic bacteria that are genetically and ecologically diverse (Ayivi *et al.*, 2020; Abedi *et al.*, 2020; Montazeri *et al.*, 2020). Lactic acid bacteria is the main microorganism involved in the fermentation of various products. They are a collection of functionally related organisms that are all fermentative bacteria and generally have no functional catalase (Kaindi, 2020). The lactic acid bacteria are naturally present in milk capable of converting lactose to lactic acid which produces a savory flavor as well as clotting tissue in the product, the process also leads to the development of aromatic substances, improved digestibility of proteins, development of sugar polymers, vitamins and useful enzymes (Montazeri *et al.*, 2020). Isolation and characterization of lactic acid bacteria residing in raw and fermented camel milk is essential in the development of functional products derived from camel milk (Nagyzbekkyzy *et al.*, 2020).

II.2. Classification of lactic acid bacteria

Lactic acid bacteria has also been classified into different genera/species based on their acid production characteristics by fermenting sugars and its growth at specific temperatures. Additionally, the lactic acid bacteria can be classified as homofermentative heterofermentative organisms based on their ability to ferment carbohydrates. The conventional approach to lactic acid bacteria classification was based on physiological and biochemical characteristics (Ayivi *et al.*, 2020). Lactic acid bacteria include genera belonging to the firmicutes phylum such as *Enterococcus*, *Lactobacillus*, *Pediococcus*, *Leuconostoc*, *Oenococcus*, *Lactococcus*, *Streptococcus*, *Weissella*, etc. Within the order *Lactobacillales* and the anaerobic *Bifidobacterium* genus belonging to the *Actinobacteria* phylum. Some starter bacteria, such as *Lactobacillus*, *Lactococcus*, and *Pediococcus*, which belong to the lactic acid bacteria (Li *et al.*, 2020; Montazeri *et al.*, 2020; Chelladurai *et al.*, 2023). Among lactic acid bacteria strains, *Lactobacillus* strains have great commercial importance due to high acid tolerance, high yield, and productivity, and can be engineered for the selective production of L/D-lactic acid (Abedi *et al.*, 2020).

II.3. Lactic bacteria in camel milk and its products

Camel milk and a range of dairy goods, including cheese and yogurt, are the main sources of lactic acid bacteria, which we shall discuss in this section.

II.3.1. Lactic bacteria in raw camel milk

Camel milk is a functional food with elevated nutritional benefits. Daily ingestion of camel milk may strengthen our immune system's defences. Despite the physicochemical makeup of camel milk, it also contains a beneficial microbiota, which is predominately made up of lactic acid bacteria. The identification of lactic acid bacteria from camel milk has already been the subject of numerous attempts (**Sharma et al., 2021**). Lactic acid bacteria, the dominating and advantageous microflora in camel milk, are a potential source of biological resources for application in dairy technology (**Fguiri et al., 2022**). In the study conducted by **Abootaleb et al. (2020)**, showed that camel milk is a rich source of probiotic bacteria. In addition, camel milk is dominated by biologically active bacteria that produce many antimicrobials, including *bacteriocins*, antifungal agents, organic acids, and hydrogen peroxide in camel milk, which probably confer to this milk its extended shelf life, evidently resulting in safer consumption even during storage for several days in the absence of refrigeration (**Rahmeh et al., 2019**).

The bulk of the strains that were recovered from camel milk were identified as belonging to the *Enterococcus*, *Lactococcus*, and *Lactobacillus species*. It was also observed that the presence of *Enterococcus* in milk was more and it is directly linked to the milking practices and surroundings of the animal sheds or farms. Earlier the same observations were also made that there is a direct contact between milking parlor and the presence of hay in the bedding which seems to promote the inoculation of milk with *Enterococcus faecalis* or *Enterococcus faecium* (**Sharma et al., 2021**). Furthermore, the present study showed that lactic acid bacteria are affected as well by the production system and lactation stage (**Fguiri et al., 2022**).

Normal microflora in camel milk is widely investigated, and the results testify to their high diversity according to different countries (**Konuspayeva et al., 2021**). Where studies have been conducted on the microbiota of camel milk. Seven genera of lactic acid bacteria were identified in camel milk from different countries, lactic acid bacteria isolates were dominated by the genus *Enterococcus* in Kazakhstan and Iran. Whereas, in Sudan and Morocco, the genera *Streptococcus* and *Lactobacillus* were identified as the major groups, respectively. Furthermore, the genus *Lactococcus* was one of the most represented genera in Morocco, Sudan, Kazakhstan and the United Arab Emirates. Besides being one of the major genera in Morocco and Kazakhstan,

Leuconostoc was the most abundant in Kenya. *Pediococcus* was the less represented genus in Morocco and Iran, whereas, the genus *Weissella* was detected only in Iran (Rahmeh *et al.*, 2019).

In a study he conducted Edalati *et al.* (2019), a total of 32 isolates were randomly chosen from 14 collected samples. They were all Gram-positive bacteria; in addition, a considerable number of yeast and catalase-positive bacteria were observed. Only eight isolates were stable after subculture and purification, these were consequently studied. After phenotypical examination, the isolates were classified into three groups of *Lactobacillus*, *Leuconostoc* and *Weissella* genera. Lactic acid bacteria were counted in camel milk using common media according to the traditional method. And in another experiment he did Zhao *et al.* (2020), fifteen fresh camel milk samples were collected from domesticated camels in a pasture of Alxa Left Banner. The bacterial diversity of camel milk samples were analysed. The camel milk microbiota was highly diverse. A small number of lactic acid bacteria sequences were detected, representing the species *Streptococcus thermophiles*, *Lactobacillus helveticus*, *Lactococcus lactis*, and *Leuconostoc Mesenteroides*. These results confirm that fresh camel milk has a high bacterial diversity and is a valuable natural resource for isolation of novel lactic acid bacteria.

Currently there are remarkable progresses in camel dairy technologies that paved the way for production of different camel dairy products. A number of experiments were conducted on camel milk processing technologies from preservation of camel milk using lactoperoxidase system activation using hydrogen peroxide and thiocyanate as well as by hydrogen peroxide producing lactic acid bacteria to metagenomic characterization of lactic acid bacteria isolated from spontaneously fermented camel milk. Lactoperoxidase system was tested for camel milk preservation, and found that chemical activation of Lactoperoxidase system extended the shelf life of camel milk. Moreover, Lactoperoxidase system activation exhibited a bacteriostatic effect against coliform count and total bacterial count and significantly decreased the rate of growth of *S. aureus* and *Escherichiacoli* counts (Yirda *et al.*, 2020).

II.3.2. Lactic bacteria in fermented milk

More than fresh milk, fermented milk is sought after by consumers who are looking for its probiotic properties (thanks to the presence of lactic bacteria) and its overall health effects (Mustafa *et al.*, 2023). Milk is an ideal medium for the growth of microbes and loses its quality within a short period of time if not preserved in some way, the spontaneous nature of milk fermentation is a traditional ancestral method. It consists of the transformation of lactose into lactic acid by the natural microflora in milk dominated by lactic bacteria and, in some cases, by yeast, traditional fermented camel milk has different names and processing methods in different countries.

The most common and popular fermented camel milk products include *shubat*, *khoormog*, *garris*, *susac*, *laben*, *ititu*, *dhanaan* and *chal* (Bekele *et al.*, 2021; Konuspayeva *et al.*, 2021; Seifu, 2023).

The fermented milk incorporates lactic bacteria that fortify antimicrobial activities towards pathogenic dealers including *Bacillus*, *Pseudomonas*, *Mycobacterium*, *Staphylococcus*, *Salmonella* and *Escherichia*. Camel milk is difficult to ferment using the usual dairy starting cultures. This resistance to acidification is thought to have been caused by antibacterial compounds in camel milk. It has now been established that proteolysis plays a key role in restricting the presence of lactic acid bacteria in camel milk as opposed to antimicrobials, which do not contribute to their suppression (Rahim *et al.*, 2020). For fermentation of camel milk, we created two consortia of lactic acid bacteria and bifidobacteria *Lactobacillus acidophilus*, *Lactococcuslacti*, *Lactobacillus acidophilus* and *Bifidobacterium bifidum*. It established that those traces of lactic acid bacteria and bifidobacteria produced exopolysaccharides and synthesized biologically low molecular peptides (Farag *et al.*, 2020).

This study was conducted to evaluate the safety and bacterial profile of *Dhanaan* (Ethiopian traditional fermented camel milk). Although the *Dhanaan* samples contained various lactic acid bacteria, they also all contained undesirable microorganisms in large proportions. The following lactic acid bacteria genera were identified: *Streptococcus*, *Lactococcus* and *Weissella*, while microbial profile of Sudanese fermented camel milk, *Gariss* and found the dominating lactic acid bacteria to be *Streptococcus infantarius*, *Lactobacillus fermentum*, *Lactobacillus helveticus* and *Enterococcus faecium* (Berhe *et al.*, 2019).

To characterize microbial communities in spontaneously fermented camel milk, in this experiment, metagenomic 16S rRNA sequencing was conducted and lactic acid bacteria were isolated with the aim to select strains that can be used as starter cultures for camel milk fermentation. The authors found that fermented camel milk was dominated by *Lactobacillales* and *Enterobacteriaceae*. *Lactococcuslactis*, *Lactobacillus plantarum*, and *Pediococcus Acidilactici* were strains of species isolated from fermented camel milk with potential use as starter cultures. Moreover, species of *Lc. lactis*, *P. acidilactici*, and *Streptococcus infantarius* are fast acidifiers of camel milk. Potentially pathogenic gram-negative microorganisms were found to be common in spontaneously fermented camel milk (Yirda *et al.*, 2020).

According to Hassani *et al.* (2022) lactic acid is considered to preserve significant constituents found in milk, it additionally, diminishes the pH which influences the actual properties of casein, and finally facilitates the digestibility in humans. According to fermentation of camel

milk enhances an increase in the concentration of amino acids, fatty acids, and organic acid hence an improvement in the nutritional value of fermented camel products.

II.3.3. Lactic bacteria in cheese

Making cheese helps preserve the valuable components of milk. By coagulating and separating the whey from milk, cream, partially skimmed milk, buttermilk, or a mixture of these ingredients, cheese can be created. Processed camel milk has excellent biological qualities because of its high concentration of antibacterial components such lysozyme, lactose, and immunoglobins (**Gemechu et al., 2023**). Starter lactic acid bacteria and non-starter lactic acid bacteria interact from the early stages of manufacture to the cheese ripening process, and combinations of starter bacteria with *mesophilic Lactobacillus spp.* Are common tools used to accelerate and conduct cheese ripening. These strategies represent an interesting approach to enhance flavour intensity or impart atypical but desirable flavour notes to cheese (**Belkheir et al., 2020**).

It should be remembered that non-cultured camel milk (pasteurized) was originally acidified only by adding lactic acid. It was mentioned that lactic acid or starters could be used for milk acidification in cheese making (**Al zoreky et al., 2021**). Additionally, the yield and quality of camel milk cheese are significantly influenced by processing factors such the quantity and kind of starter culture, heat treatment, and rennet. thermophilic starter cultures are more effective in acidifying camel milk, and a higher cooking temperature is advised for camel milk curd in order to increase the cheese yield (**Seifu, 2023**).

microflora playing important role both for antimicrobial activity and on acidification which is essential for cheese processing. The starters used in camel milk processing for fermentation or cheese making (mesophilic, thermophilic or their mixtures) lead to an acidification rate at 37°C between 33% and 79% lower than for cow milk. In the published literature regarding physico-chemical and rheological. Starters as thermophilic ones containing *Lactobacillus helveticus*, and *L. lactis* or *Streptococcus thermophilus*, known for their high-acidifying power can be used to also improve the acidification process. However, as for the management of fermentation to get specific fermented products, camel cheese manufacturing is not using starters made with lactic bacteria isolated from camel milk. The identification of lactic acid bacteria strains unique to camel milk that can produce the cheese characteristic aroma and enrich the varieties of camel cheese that are offered to consumers may be a challenge for scientists and cheese makers (**Konuspayeva et al., 2021**).

Starter cultures are added to cheese milk for acidification through the production of lactic acid, resulting in a decrease in pH, thus affecting several aspects of the cheese manufacturing

process and finally cheese composition. A few trials have focused on evaluation of cheese from camel milk by direct acidification of milk and using starter cultures of lactic acid bacteria, manufacture of fresh soft white cheese, and investigation of physicochemical properties and consumer acceptability of soft unripened cheese (**Bekele et al., 2019**). While camel milk cheese does not mix well with mesophilic cultures, according to a study, they produce cheese that has an unpleasant texture as a by product. Based on the acceptance and general quality of camel milk cheese, however, thermophilic and mozzarella cultures yielded better outcomes. Commercial starter cultures must be stored in deep freezers and are shipped in sealed freeze-dried pouches. The ASAL pastoralist areas, on the other hand, do not have deep freezers, making it impossible to produce different batches of camel cheese using commercial cultures (**Oselu et al., 2022**).

II.3.4. Lactic bacteria in yogurt

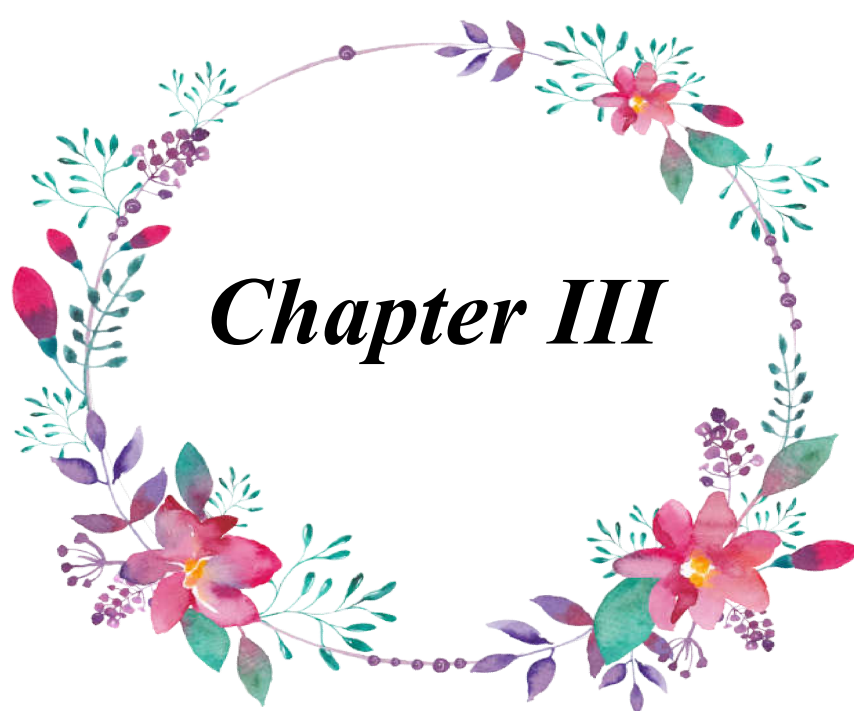
Yoghurt is a dairy product produced through the fermentation process of milk carried out by a group of bacteria known as lactic acid bacteria. The lactic acid bacteria convert milk sugar (lactose) into lactic acid, giving yoghurt its texture and characteristic tang (**Moh et al., 2021; Shori et al., 2022**).

There is ample literature on the possibility of making yogurt with camel milk. Several strains of conventional lactic bacteria have been tested as *Lactobacillus bulgaricus* or *Streptococcus thermophilus*, but also *L.acidophilus*, *L.casei*, and *bifidobacteria*. However, the manufacture of camel milk yogurt poses a texture problem, with the product appearing ultimately unpleasant to the palate (**Mustafa et al., 2023**). Moreover, for probiotics bacteria to be effective in improving health, yogurt must contain abundant and viable microflora at the time of consumption, and this is stated in the food laws of many countries. Having said that, providing favorable conditions of surviving a sufficient number of lactic acid bacteria in yogurt has always been a key challenge in the dairy industry. Although there are no academic reports yet, people who consume this type of yogurt believe that adding these bio-compounds to yogurt improves its taste or maintain yogurt quality for a long time (**Hosseini et al., 2021**).

Reported that **Ho et al. (2022)** traditional approaches to produce yoghurt from bovine milk are not applicable to camel milk. Fermentation of camel milk via starter cultures (e.g. *Streptococcus thermophilus* and *Lactobacillus delbruckii subsp. bulgaricus*, 2.5%) and incubation at 37 °C for up to 16 to 18 h did not form the desired curd structure, but instead formed fragile and heterogeneous dispersed fakes with a watery texture.

Despite these challenges, many attempts have been made to improve the firmness and consistency of camel milk gels and prevent syneresis of the product during processing and storage. Use of microbial transglutaminase preparation can be an effective way to solve this problem, is a transferase which catalyzes the acyl-transfer reaction between γ - carboxamide groups of peptide or protein bound glutamyl residues and primary amines. Cross-linking of milk proteins by microbial transglutaminase modifies functionalities such as hydration ability and rheological as well as emulsifying properties, is effective in reducing syneresis in acid milk gels and has been reported as a method of improving the texture and shelf-life of yoghurt (**Chen *et al.*, 2019; Mohamed *et al.*, 2019; Waktola *et al.*, 2020; Bulca *et al.*, 2022; Patel *et al.*, 2022**).

Since fermentation of camel milk results in a product with weak consistency, **Kamal Eldin *et al.* (2020)** studied the influence of supplementing cow milk with increasing levels of camel milk (0-60%) on different properties of yogurt. Fresh raw camel and cow milk were heated separately at 85°C for 5 min and mixed before fermentation with lactic acid bacteria. It was found that addition of camel milk to bovine milk led to larger and less differentiated casein micelles. After fermentation, the pH of all yogurts was 4.5 to 4.6 and it decreased to 4.3 after 2 weeks of storage suggesting that the soft gels caused by the addition of camel milk is due to the structure and concentration of its proteins rather than limitations related to bacterial growth.



Chapter III

This section considered a global summary on camel milk by-products: citing respectively fermented milk, cheeses, yogurts, powdered milk and other products. We have tried to highlight new research in this sector (**figure 02**).



Figure02: Camel milk and its products(Seifu, 2023)

III.1 Fermented camel milk

The microflora biodiversity leads to a rich diversity of fermented beverages prepared from camel milk. Moreover, fermentation is one of the oldest methods of consuming camel milk. Camel milk producers living in different regions of the world have their own varieties of fermented products with specific taste, texture, and flavour. Each camel country has described their traditional fermented milk in terms of microbiological, physicochemical, and chemical properties, as well as volatile organic compound profiles in some cases(Konuspayeva *et al.*, 2021).

The most known fermented camel milk products described in the literature are *shubat* in Kazakhstan and China , Other traditional fermented beverages based on a mixture of camel milk

and water are available in Mauritania known as *zrig,laben* in Arabic countries, in Morocco known as *Lfrik*, and in Iran and Turkmenistan known as *chal* (Konuspayeva *et al.*, 2021), *khoormog* in Mongolia (Guo *et al.*, 2021), *garris* in Sudan, Somalia and Sudan Camel milk, *shubat* in Turkey, *suusac* in East Africa, Kazakhstan (Faccia *et al.*, 2020; Marete *et al.*, 2023), *suusac* in Kenya (Maith *et al.*, 2019), and *ititu* and *dhanaan* in Ethiopia (Berhe *et al.*, 2019). However, there is a trend to standardize the starter cultures types for acidification in making *garris* and *suusac* (Faccia *et al.*, 2020; Ahmed *et al.*, 2022). Fermented camel milk products are said to offer health-promoting advantages because of their anti-inflammatory and antioxidant qualities, improved flavor, and ease of storage (Kamal-Eldin *et al.*, 2022; Muthukumaran *et al.*, 2022).

Some of the strategies that could be applied in order to improve quality camel fermented the study found that the addition of 8.0% date syrup to fermented camel milk improved the nutritional quality, as it increased the levels of total solids, ash, and potassium of the developed product. Overall, this innovative new flavored fermented camel milk can be of high nutritional and health value and could attract consumers, as it did not contain refined sweeteners, artificial additives, and preservatives (Shahein *et al.*, 2022). where reported that Zhaxybayeva *et al.* (2020) in his study that The addition of enzyme (transglutaminase), prebiotic fructooligosaccharide and nutrient additive (apple pectin) to camel milk positively affected such properties as organoleptic, viscosity, and moisture-retention capacity of the product.

III.2 Camel milk cheese

Camel milk cheese is a recent product that enters into both the domestic and global milk product markets. Cheese made from camel milk can have processing issues and be of lower quality if it is produced using the same technology as dairy products made from cow milk. Camel milk cheese had a very high pH and high moisture content. Additionally, depending on how the cheese is processed and how the whey is drained, the majority of the total solids constituents, such as protein and fat, are gradually concentrated into the cheese curd. Furthermore, throughout the cheese-making process, the type, ash level, and salt addition can all have an impact on the minerals present in the cheese (Bekele, 2022).

Compared to cow milk, camel milk contains 26% more β -casein in a specific volume of milk. Camel milk also has low κ -casein (3.5%) than cow milk (13%). On the other hand, the amount of κ -casein in camel milk is considered less, contributing to its coagulation challenges in cheese making. However, milk coagulation is obtainable through enzymatic hydrolysis of κ -casein at the surface of casein micelles (Oselu *et al.*, 2022).

Rennet is the most popular coagulant used by cheese-makers to manufacture many different types of cheese. An increase in acidity, prolonged heating, or enzyme activity could cause coagulation. Cheese manufactured from a combination of cow and camel milk has better aroma, appearance, hardness, and textural qualities than cheese made exclusively from camel milk. Hence, this finding was designed to evaluate the impacts of mixing cow milk with camel milk on milk coagulation, cheese yield, and chemical composition and sensory attributes of the cheese (**Gemechu *et al.*, 2023**). Camel milk is used with sheep milk for production of white soft cheese, with buffalo milk for the production of soft cheese (**Bouras *et al.*, 2023**), and with cow milk for the production of Mozzarella cheese (**Abdallah *et al.*, 2022**).

Cheese is found to be a good method of preservation of perishable milk into more shelf stable dairy products. Nutritionally, it is well commendable for supplying the required nutrients to our body. The taste is also acceptable and endured in the community. Attempts were made to manufacture dairy products such as feta cheese, and soft brined cheese from camel milk that had been produced at laboratory level (**Yirda *et al.*, 2020**). **Konuspayeva *et al.* (2021)** claims that when Feta or mozzarella-type cheese is manufactured with camel milk, the results are frequently unsatisfactory because the flavor, consistency, and texture differ greatly from the cheese counterpart made with cow milk (**figure 03**).

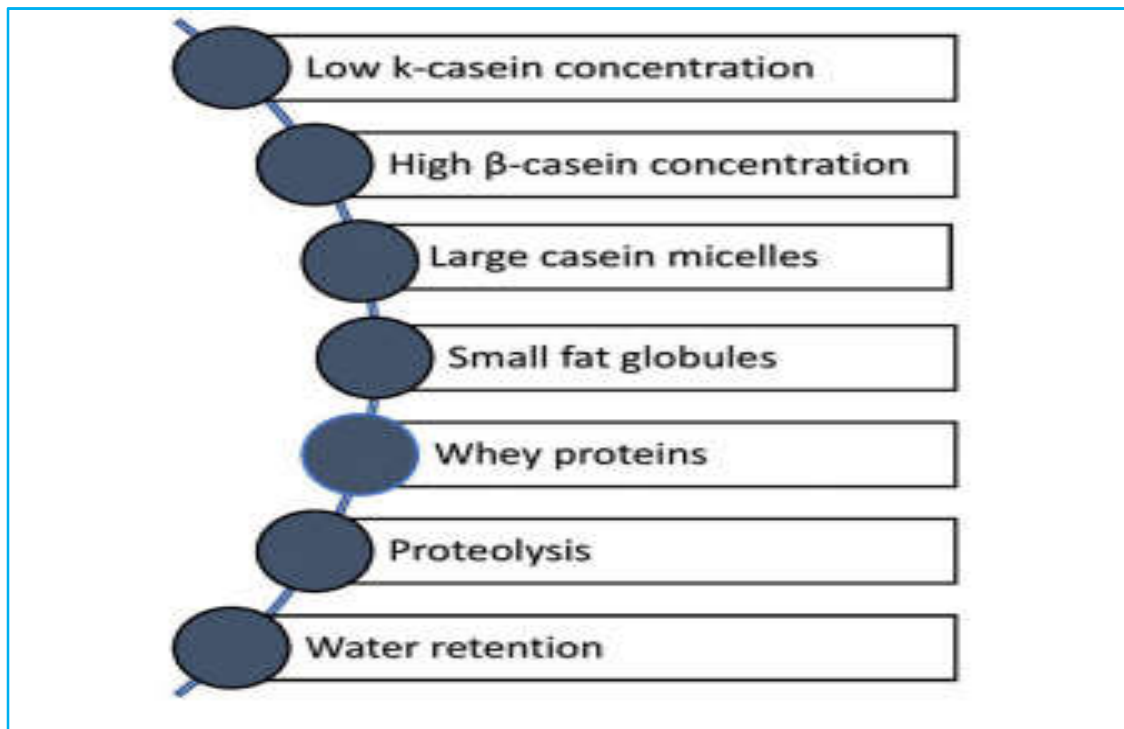


Figure (03): Milk compositional factors that contribute to the soft texture of camel milk cheese (**Mbye *et al.*, 2022**).

III.2.1 Coagulation enzymes

The camel milk ability to coagulate may be increased by adding cow milk to the mixture. Additionally, found that a higher chymosin content could reduce the time required for milk to coagulate, which is somewhat consistent with the investigation (**Gemechu *et al.*, 2023**). According to study findings **Bouras *et al.* (2023)** that the addition of goat milk to camel milk considerably increases the performance of camel milk to coagulate with camel rennet. Subsequently, the reducing of coagulation time increases the cheese-making ability of camel milk. So, the optimum pH and temperature pairs are subsequently used in fresh cheese processing using camel rennet or microbial rennet. The type of rennet used had a significant effect on the overall quality of the cheese. It was therefore construed that the enzymatic extract of camel rennet can be a strong competitor of microbial rennet in terms of cheese yield in camel-goat cheese. There appeared a clear impact of the type of enzyme on the composition of the fresh cheese. Fresh cheese were also made from camel milk only using different proteolytic enzymes. With a view to improving the coagulation of camel milk, Study aims **Bouras *et al.* (2023)** to at the valorization of chicken pepsin in the manufacture of a new fresh cheese based on camel milk and goat milk in comparison with commercial rennet. Chicken pepsin cheese was more accepted by the twenty tasters than commercial rennet cheese with a score of 8.4 ± 2.45 . These results show the possibility of reinforcing the lactic gel of camel milk during coagulation when it is mixed with goat milk and of considering the use of chicken pepsin in this type of cheese processing by ensuring good quality cheese obtained.

III.3 Camel milk yoghurt

Consumption of yogurt has increased day to day life because it fulfils many of the current die try needs. The usefulness outcome of yoghurt could be increased by the effect of bioactive peptides which are reproduced through the process of storage and fermentation (**Erina *et al.*, 2021**). Where the yogurt preparation from camel milk is quite challenging because it is low in casein, devoid of β -lactoglobulin and owing to significant concentration of antimicrobial agents, that reduces the lactic acid bacteria efficiency (**Khaliq *et al.*, 2022**).

Chen *et al.*, (2019); Shegaw *et al.*, (2020); Waktola *et al.*, (2020); Ho *et al.*, (2021) and (2022) mentioned that the gel texture of yoghurt is crucial in determining its look, mouthfeel, and overall consumer appeal. However, due to camel milk low coagulation, which causes a thin consistency and fragile product structure, camel milk yoghurt manufacture is difficult. The paucity of interactions between κ -casein, large size of casein micelles and β -lactoglobulin is the main cause of the weak coagulum in camel milk. There is ample literature on the possibility of making yoghurt

with camel milk. Other reasons are the whey proteins to caseins ratio in cow milk varies in a range from 15,85% to 25,75% depending on the season, diet, breeding and genetic polymorphism while this ratio in camel milk is 24,76% to 27,73% (**Roy et al., 2020**).

However, the manufacture of camel milk yoghurt poses a texture problem, the product appearing sticky and ultimately unpleasant to the palate (**Shegaw et al., 2020; Alhadrami et al., 2022**). Many quality problems, such as low viscosity or high syneresis, which occur during milk product manufacturing, are often solved by increasing the total solid or adding stabilizers, such as milk powder, modified starch, carrageenan, guar gum, pectin, gelatin and sodium caseinate. Yoghurt from camel milk stabilized with gelatin and corn starch was acceptable and comparable with cow milk yoghurt. Stabilizers and polysaccharide producing cultures have also been used to improve texture and prevent syneresis (**Shegaw et al., 2020; Ho et al., 2022**), skim/non-fat dry milk powder, (polymerized) whey protein isolate, stabilizers (e.g. Grindsted ES255), modified starch, Na₂EDTA, and even mono- and di-glyceride fatty acids (**Ho et al., 2022**). Incorporation of monk fruit sweetener into camel milk yogurts significantly decreased the pH and increased the viscosity of yogurts. Monk fruit sweetener can be used as a zero caloric health-beneficial sweetener in the production of yogurt made with camel milk (**Buchilina et al., 2021**).

Other authors have made improvements to camel milk yogurt production by blending it with milk from other species or by adding 0.75% biosynthetic xanthan, albeit with dubious results in terms of organoleptic characteristics. a "drinking yogurt" without having the taste qualities, even by adding natural or synthetic aromas. These difficulties explain why there is no industrial production of camel milk yogurt at present (**Mustafa et al., 2023**).

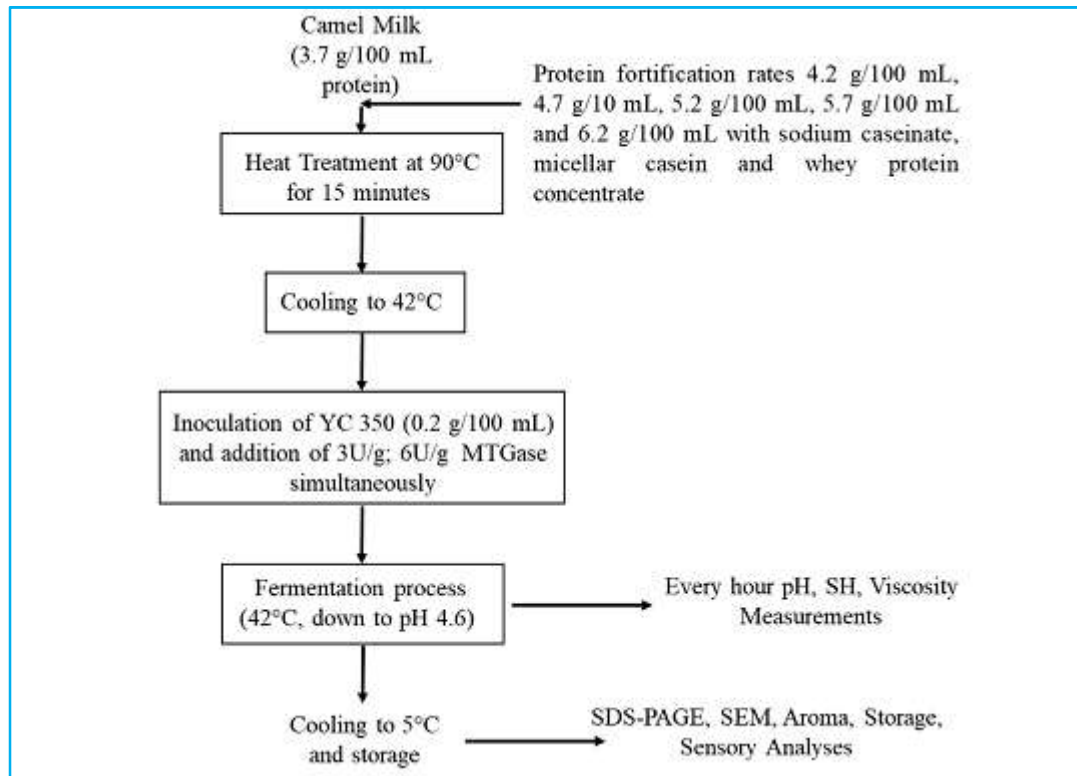


Figure (04): Scheme of camel milk yogurt production(Bulca *et al.*, 2022).

The manufacturing process for camel milk yogurt is shown in (figure 04). Different kinds of cow milk protein powders were added to raw camel milk and mixed with a homogenizer (IKA-T18 digital Ultra-Turrax, rpm x 1000). Afterward, heat treatment was applied at 90°C for 15 min, followed by cooling to 42°C using a water bath (Faithful Instruments,DKL-2000-IIIIL). MTGase enzyme (3 and 6 U/g protein) and direct vat set (DVS) starter culture (YC-350, 0.2 g/100 mL) were added to heated camel milk simultaneously at 42°C. During fermentation, pH, SH, and viscosity were measured hourly(Bulca *et al.*, 2022).

III.4 Camel milk powder

Camel milk powder is manufactured and marketed in the Middle East and beyond (Yirda *et al.*, 2020), where powder milk is the best way to preserve this highly perishable product for later consumption (Konuspayeva *et al.*, 2021; Chhasatiya *et al.*, 2022; Zou *et al.*, 2022). Moreover, camel milk being produced often in remote places far away from consumption basin, it is the only solution to transport high quantity of milk by removing the water it contains (88 to 90% of the weight). The advantage is also the conservation of the nutritive value of the liquid milk. To make camel milk powder, two main modern technologies were used: spray-drying (hot-drying) and lyophilization (freeze-drying) (Konuspayeva *et al.*, 2021; Chhasatiya *et al.*, 2022).

In process freeze drying, camel whole milk was transferred to glass beakers or petriplates for freezing in deep freeze refrigerators, then the frozen milk samples were freeze dried using a benchtop freeze drier. Freeze dried powder was crushed manually with a glass rod to have uniform powder. In another process to obtain camel milk powder, whole and skimmed concentrated camel milk was spray dried using a pilot spray dryer. The temperature of inlet air was 170 ± 5 °C and outlet air temperature was maintained at 70 ± 5 °C. The feed rate was maintained at 50 mL/min using a peristaltic pump and feed temperature was kept at 50 °C in an insulated stainless-steel container. The obtained camel milk powder samples were stored in metallized laminate under dry conditions, This process is called spray drying (**Deshwal *et al.*, 2020**).

III.5 Camel milk butter and other fat products

The majority of the respondents reported that it is difficult to make butter from camel milk. However, small proportion of pastoralists and agro-pastoralists reported that they mix camel milk with cow and goat milk when intending to make butter some respondents revealed that butter can be made from camel milk when fermentation is undergone for 7 days (**Bekele *et al.*, 2021**).

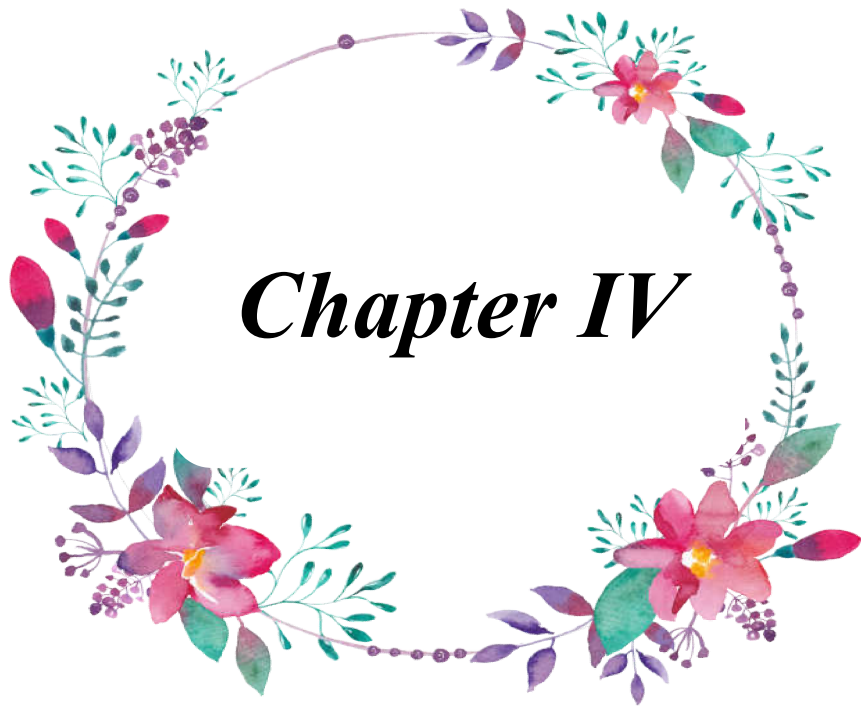
In comparison to cow milk, large quantity of camel milk is required to obtain a small amount of butter. Camel milk cream has to be churned at a higher temperature (22–25°C) than cow milk (8–14°C) to obtain a reasonable amount of butter. Camel milk butter has lower (12–13%) moisture content than cow milk butter (15–16%) and this may be the reason for the sticky texture of camel milk butter. Camel milk butter has white colour and waxy appearance(**Seifu, 2023**). The difficulty of processing camel milk into butter is also attributed to the little tendency of camel milk to cream up due to deficiency of the protein agglutinin(**Oselu *et al.*, 2022; Seifu, 2023**).

III.6 Camel milk ice cream

Ice cream and frozen desserts are popular and widely consumed dairy products especially in countries with hot climate such as the Middle East (**Muthukumaran *et al.*, 2022**). Currently, camel milk ice cream is made commercially in the United Arab Emirates, Kazakhstan and Morocco (**Konuspayeva *et al.*, 2021**). In Mongolia, a soured cream called Orom is produced from bactrian camel milk. Its production involves heating camel milk at 75–85°C with continuous mixing to make foams, cooling to 18–20 °C, and keeping it at this temperature for 10–15h. The soured cream obtained, Orom, is usually consumed fresh (**Seifu, 2023**).

III.7 Camel milk chocolate

The consumption of chocolate and cocoa products are increasing worldwide. The major ingredient of chocolate ie cocoa contains a significant amount of fat (40–50% as cocoa butter, with approximately 33% oleic acid, 25% palmitic acid, and 33% stearic acid) while, polyphenols constitute around 10% of the whole bean's dry weight(**Khan, 2023**). Chocolate products manufactured camel milk contain ~ 21% pure camel milk powder. In the United Kingdom , these products are available online or in stores (**Horigan et al., 2020**).



Chapter IV

Although camel milk is not as widely consumed as cow milk is, it is still well-known in many nations and cultures and has a number of health advantages over other types of milk. Camel milk has a lot of health benefits, including interesting medical. The highlights of this chapter include there are many benefits preventive or curative benefits of camel milk, thus we have divided this chapter into three sections: the first covers internal diseases, the second covers cancer, and the third covers cutaneous diseases.

Part one: Internal diseases

In this section, we'll talk about internal ailments, since diabetes, hepatitis, and conditions affecting the digestive system are so common and have so much research on them, we've chosen to examine them.

IV.1. Diabetes

Diabetes is a chronic metabolic disorder characterized by numerous disturbances in carbohydrate, protein and fat metabolism (**Sboui et al., 2022**). It is also characterized by a high level of blood sugar (i.e. glucose) that results from the body's failure to produce enough insulin (type 1 diabetes) or from the inability to respond appropriately to insulin (type 2 diabetes) (**Ali et al., 2019; Khaliq et al., 2019; Bhatishwar et al., 2021; Humaira et al., 2021; Swelum et al., 2021; Sboui et al., 2022**), glucose homeostasis is achieved through the coordinated actions of glucagon hormone (secreted by α pancreatic cells), which increases blood glucose, and insulin hormone (secreted by β -pancreatic cells), which decreases blood glucose (**Hoda et al., 2023**).

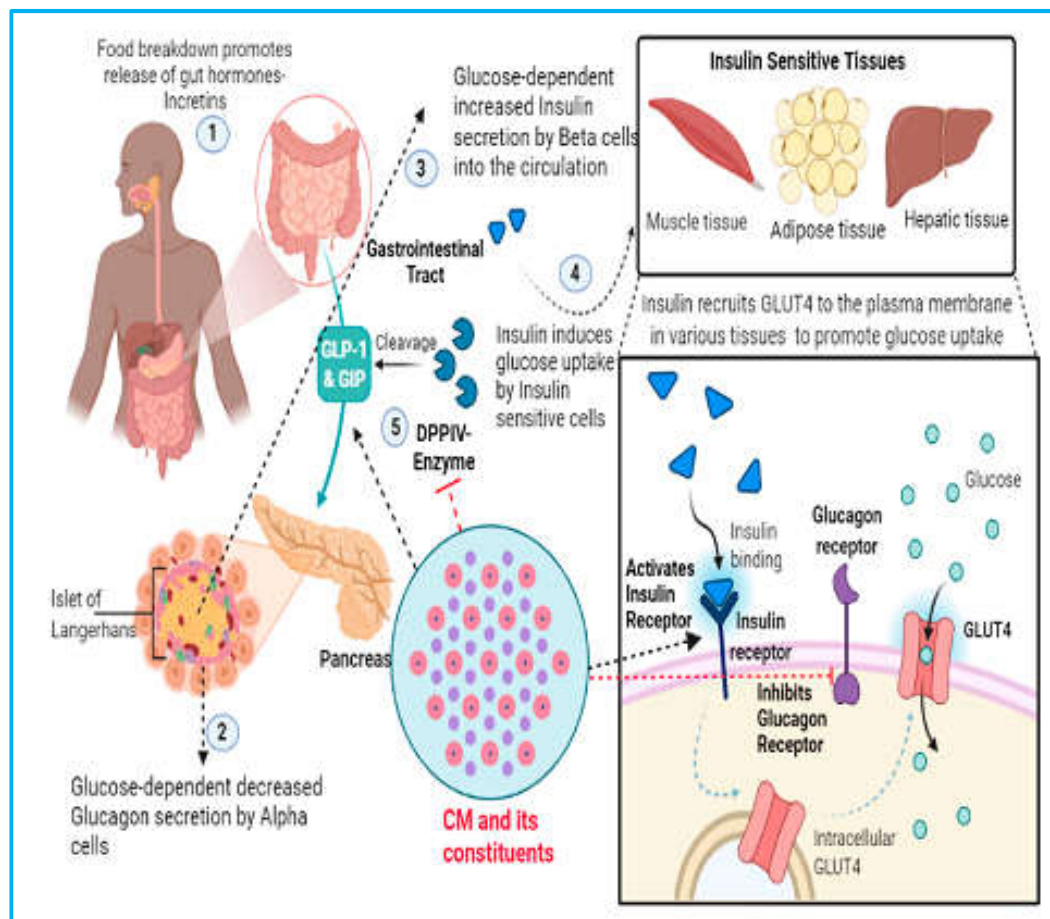
The most researched component of camel milk is its ability to treat diabetes (**Swelum et al., 2021; Zheng et al., 2021**). These research looked at a number of diabetes-related issues, including blood sugar, lipid profiles, insulin production, and resistance, and showed that camel milk dramatically improved these issues. The positive effects of camel milk in treating illnesses related to diabetes and its complications have even been studied in numerous randomized clinical trials in people (**Fallah et al., 2020; Zheng et al., 2021**). And **Elhassan et al. (2022)** recently reported in a study that camel milk and its derivatives play the same role. The thing is the role of insulin in lowering blood sugar.

Camel milk contains insulin and insulin-like peptides that have biological and pharmacological properties much greater than that noted in bovine milk and is high in vitamin C, vitamin E, glutathione, and other antioxidants (**Almohmadi, 2020; Digiacomo et al., 2022**). According to (**Elkot et al., 2019; Abd El-Aziz et al., 2022; Stephen et al., 2022**) camel milk

insulin is engulfed within micelles and protected from proteolysis in the upper gastrointestinal tract. It is encapsulated in nanoparticles that make it easy for the human system to absorb and easily pass it to the blood stream. Many studies have demonstrated that the insulin in camel milk is rich in half as many cysteines as human insulin peptides (**Khaliq *et al.*, 2019; Fufa *et al.*, 2020; Mohammadabadi *et al.*, 2021 and 2022**).

In general, the effect of camel milk is reflected in an increment in insulin secretion, decrement in insulin resistance, and improvement of the lipid profiles. More specifically, camel milk may have a direct effect on the function of the insulin receptors and glucose transport, it may influence the secretion of insulin by the pancreatic β -cells, and may influence the overall activity of the pancreatic cells. These insulin-like proteins are stable, resist proteolysis, are not degraded by the acidic environment of the stomach, and therefore, can reach the target tissues (**Akbar *et al.*, 2020; Agrawal *et al.*, 2020; Vincenzetti *et al.*, 2022**).

Food breakdown in the gastrointestinal tract leads to release of gut hormones, such as Glucagon-Like Peptide-1 and Glucose Dependent Insulinotropic Polypeptide, which seemingly stimulate glucose-dependent insulin secretion by the pancreatic Beta cells. Insulin thereby promotes glucose uptake by the insulin sensitive tissues. Mechanistically, insulin, upon binding to insulin receptors, initiates a signaling cascade that eventually induces translocation of glucose receptors to the membrane whereby glucose can be up-taken. These gut hormones are cleaved by DPP-IV enzymes which leads to attenuation of insulin secretion. Interestingly, camel milk and its constituents have been reported to activate GLP1/GIP and inhibit Dipeptidyl peptidase-IV, activate insulin receptor and inhibit glucagon receptor. Additionally, it has been reported that camel milk embodies insulin-like peptides that mimic insulin responses, another aspect adding to their anti-diabetic potential (**Izadi *et al.*, 2019; Khan *et al.*, 2022; Mohammadabadi *et al.*, 2022**) (figure 05).



Figure(05):Representative image delineating the plausible anti-diabetic effect of camel milk (**Khan et al., 2022**)

Recent in vitro studies have shown targeting and positive modulation of Infrared and its signaling pathway intracellular by camel milk proteins and peptides (**Irfa et al., 2022; Khan et al., 2022**).

Plasma lipids, lipoprotein profile and triglycerides are varied in diabetic patients, so that vascular complications occurred and the risk of heart failure can be interceded. Low cholesterol level is necessary to decrease these health risks of diabetic patients either through drug therapy or dietary plans a reduction in amount of Low-density lipoprotein in patients suffered with type 1 diabetic when treated with camel milk up to 6 months. Studied that after 3-month trails of camel trails on diabetic patients of type 1, the lipid profile has been reduced by three-fold (**Akbar et al., 2020**).

Mohammadabadi et al. (2022) concluded that theusing of camel milk for 45 days significantly decreased hyperlipidemia, total cholesterol, triacylglycerol's, free fatty acid, low-density lipoproteins, and very low-density lipoproteins in plasma, liver, heart and kidney

towards normal levels. Also, after consumption of camel milk, the content of high-density lipoproteins significantly improved.

It was discovered that camel milk is rich in healthy fats that lower harmful cholesterol levels in the body, safeguarding the body and avoiding ailments of the heart and arteries like high blood pressure (**AL-Moosawi et al., 2023**).

IV.2. Hepatitis C and B

Hepatitis C virus is spread worldwide and so far no effective treatment is available. To combat the disease, often use the Egyptian patients' traditional medicines, such as recording of camel milk, which contains lactoferrin Protein (**Kedir Abdi, 2021**).

Scientific publications have shown that camel milk cures both hepatitis B and hepatitis C. The special fat in camel milk soothes the liver and has a beneficial action on chronic liver patients. There is also a possibility that the relatively high concentrations of ascorbic acid in camel milk help in improving liver function. Subsequent studies have shown that camel lactoferrin markedly inhibits hepatitis C virus genotype 4 infection through preventing the entry of the virus into the cells (**Muhammad Abdul et al., 2020; Sumaira et al., 2020; Al Nohair et al., 2021; Bhatishwar et al., 2021**).

The camel milk lactoferrin stops Hepatitis C virus entry and replication in infected HepG2 cells two times higher than lactoferrin in human, bovine, and sheep milk. Not only this, but camel lactoferrin immunomodulatory role is exemplified by the fact that it modulates the activation and maturation of various immune cells such as neutrophils, macrophages, and lymphocytes (**Neelam et al., 2022**).

IV. 3. Diseases of the digestive system

Camel milk contains various protective proteins with antimicrobial and immunological properties. Camel milk Igs combat autoimmune diseases by strengthening the immune system and protects the body against microbial and viral infections. Lysozymes that invade pathogens and damage the bacterial cell wall and enhance the immune system. Lysozymes are usually specialized in enhancing immunity against pathogens but immunoglobulins are related to body infections (**Mohammadabadi et al., 2021**).

IV.3.1. Antiviral

Neelam *et al.* (2022) reported that, generally, camel milk lactoferrin may directly interact with viral molecules or receptors (heparan sulfate) on the cell surface and prevent the virus attachment to the host cells and thus hinder infection. The virucidal mechanism of camel milk lactoferrin depends on its alpha-helical structure and cationic nature. The antiviral effects of lactoferrin from camel milk have been demonstrated against many viruses. The mode of action behind this activity is the neutralization of virus particles and inhibition of their replication.

IV.3.1.1. Anti-Diarrheal

According to a study, camel milk contains many “protective proteins” like lactoferrin, lactoperoxidase, Nagase and Peptidoglycan recognition protein that exert immunologic, bacteriocidal and viricidal properties. Among the “protective proteins” in camel milk lysozyme, lactoferrin, lactoperoxidase and Peptidoglycan Recognition Protein have anti-diarrheal, antibacterial action as well as high titers of antibodies against rotavirus, and the impact on the immune system. It should be noted that rotavirus is the most common cause of diarrhea in children under 5 years old. Since camel milk is rich in anti-rotavirus antibodies diarrhea subsides (Akbar *et al.*, 2020; Hassan *et al.*, 2020; Bhatেশwar *et al.*, 2021).

IV.3.2. Antibacterial

The levels of lactoferrin and lysozyme are significantly higher in camel milk than in cow milk. Past studies have confirmed that lactoferrin functions as either a bactericidal and/or bacteriostatic agent. This is why camel milk also has an inhibitory activity against Gram-positive and Gram-negative bacteria such as *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella Typhimurium* infections (Bhatেশwar *et al.*, 2021; Singh *et al.*, 2021; Hassani *et al.*, 2022; Stephen *et al.*, 2022).

IV.3.3. Gut disorders

Lactose intolerant people can drink camel milk without experiencing any negative side effects (Khaliq *et al.*, 2019). Compared to cow milk, camel milk appears to be easier to digest and has less of an impact on lactose sensitivity issues. One possible explanation is that camel milk might generate less caseomorphine, which would result in more lactose being exposed to lactase for digestion. According to Mohammadabadi *et al.* (2021), camel milk high anti-inflammatory protein content has beneficial effects on stomach and intestinal problems.

Part two: cancer

in vitro studies have revealed the inhibitory effects of camel milk and its constituents against various forms of cancer, apparently through induction of apoptotic pathways. In parallel, animal experimental data have also demonstrated the inhibitory potential of camel milk and its constituents against various forms of cancer (**Khan et al., 2022; Neelam et al., 2022**).

IV.1. Therapeutic role of camel milk in different type of cancer

Studies have shown that camel milk can inhibit the proliferation of cancer cells through different mechanisms, including apoptosis, anti angiogenesis, cytotoxicity, and antioxidant effects. It has been found to have an anti proliferative effect in human hepatoma HepG2 cells, human breast cancer MCF7 cells, human colorectal HCT116 cells, and esophageal carcinoma cells (Eca109). Additionally, camel milk proteins can activate the caspase-3 mRNA and activity and the induction of death receptors in HepG2 and MCF7 cell lines (**Galali et al., 2019; Khan et al., 2021**). Moreover, several studies have been reported that camel milk contain sufficient concentration of Lactoferrin (iron-binding protein) and immunoglobulins, that play an important role to prevent the cancer development and have anticancer effects (**Khan et al., 2021; Arain et al., 2022 ; Ibrahim et al., 2022**). Very recently some researchers stated that camel milk can inhibit the tumor and malignant cells of a number of cancers such as, human glioma cells, lung cancer cells and leukaemic cells (**Galali et al., 2019**). **Ibrahim et al. (2022)** indicated that the proteolysis of whey GlyCAM-1 protein by the endogenous plasminin camel milk can help to understand the anticancer properties of camel milk. Our data explore for the first time that lactophorin undergoes cleavage at specific sites to produce unique 8 kDa C-terminal peptides with potential anticancer activities. Anticancer activity uniquely involves the generation of excessive intracellular ROS and subsequent induction of apoptosis in both colorectal and breast cancer cells. Based on the results of this study, lactophorin in camel milk can be a promising candidate for nutraceuticals and therapeutics against cancers. The potent anticancer activity of camel lactophorin and its new peptides found in this study would merit pharmacokinetic studies and clinical trial investigations that could have benefits for cancer patients.

IV.2. Effects of camel milk on colon cancer

Camel milk components inhibit the growth of colon cancer cells. Lactoferrin, a glycoprotein has a high affinity for iron and may aid cell proliferation by transporting iron into cells. Lactoferrin has also been shown to have a variety of biological activities. It interacts with polysaccharides ligands on cell surfaces and may activate cell signalling pathways such as the fas pathway, resulting

in the inhibition of tumour growth via apoptosis. Lactoferrin can also penetrate cells and function as a transcription factor, activating the transcription of specific DNA sequences. Thus lactoferrin has potential in tumour treatment by blocking tumour cell proliferation. Furthermore, lactoferrin also inhibited DNA damage, providing the further therapeutic potential for camel milk lactoferrin (Bhateshwar *et al.*, 2021). However, some studies showed the *in vivo* anticancer activity of camel milk and its constituents on colon cancer. For example, high concentration of camel milk lactoferrin induced growth arrest in colon cancer cells (Abdallah, 2021; Bhateshwar *et al.*, 2021). An experiment by Al-Omari *et al.* (2019) showed that camel milk whey reduced the early stage development of colorectal cancer and colon inflammation symptoms in a colorectal cancer mouse model that may have been mediated by down-regulation of pro-inflammatory cytokines and up-regulation of IL-10. Also, camel milk whey has a significant effect on the reduction of iNOS gene expression.

Part three: covers cutaneous diseases

IV.1. Food Anti-allergies

Adults and children are suffering from different food allergies in every part of the world (Hassani *et al.*, 2022).

Children with severe food allergies improved quickly with camel milk. Because camel milk has the following qualities, its proteins are essential for avoiding and treating food allergies.

a) Beta-lactoglobulin is absent from camel milk.

b) Different beta-caseins are present in camel milk.

c) Another important aspect is that immunoglobulins in camel milk are the same as those in human milk, reducing allergic reactions in youngsters and enhancing their ability to react to food in the future (Khaliq *et al.*, 2019; Fufa *et al.*, 2020; Mohammadabadi *et al.*, 2021; Polidori *et al.*, 2021; AL-Moosawi *et al.*, 2023).

IV.2. Treatment for skin conditions

After our research, we found that camel milk is curative for some skin diseases such as acne, eczema, and psoriasis.

Researchers have been concerned about the effects of camel milk consumption and its impact on the skin (Galali *et al.*, 2019). Camel milk provides a variety of vitamins and minerals, including vitamin B and C. It is used to treat skin conditions such as acne, eczema, and infections (Hassan *et al.*, 2020; Sumaira *et al.*, 2020; AL-Moosawi *et al.*, 2023).

According to **Mohammadabadi *et al.* (2020)** the application of camel milk cream containing 40% raw camel milk showed very good results in psoriasis patients. Itching, skin redness and dryness reduced when 20 patients with psoriasis were treated with 2 x camel milk cream for four weeks, daily.



Conclusion

We conclude our review in which we touched on the components of camel milk, the lactic bacteria of camel milk and its products, and camel milk products and its health benefits.

in the first chapter, we noticed camel milk has an opaque white color and occasionally tastes salty. According to numerous studies, camel milk keeps its quality for 12 days while cow milk only keeps its qualities for two days at the same temperature. Studies show that the average protein content of camel milk is between 3% and 3.90%. Additionally, depending on the season, milk protein concentration changes. Lactose sugar makes up the majority of the carbohydrates in camel milk. Calcium, phosphorus, magnesium, sodium, potassium, and chlorides are the primary minerals found in milk. It is generally stated that camel milk contains also high quantities of trace elements, especially iron and zinc. Camel milk contains more iron than other milk. camel milk is particularly high in vitamins D, E, C, and A, Water is the most important factor in camel milk. the water content of camel milk increases during dehydration. where the water content of camel milk fluctuates from 84% to 90%.

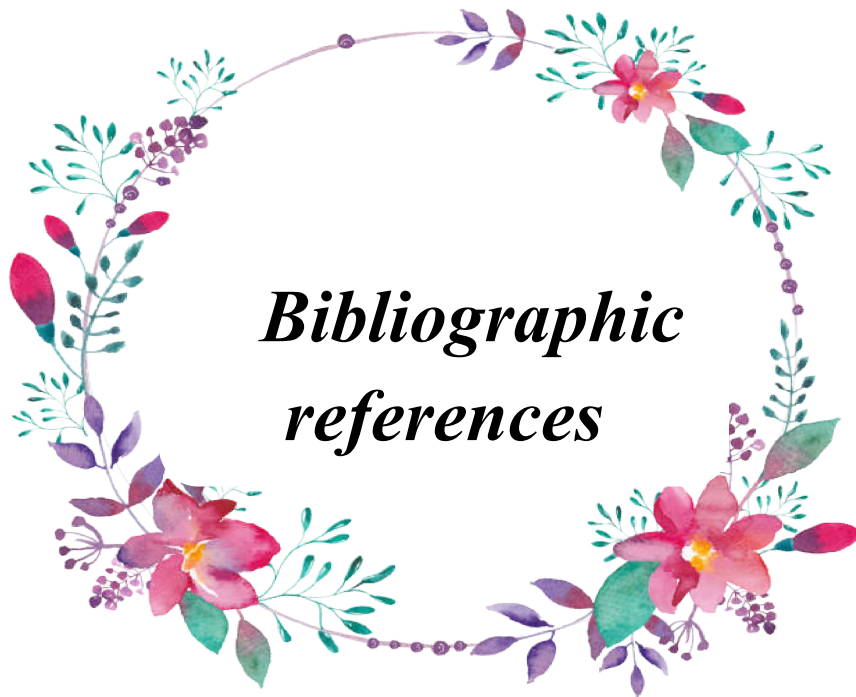
In the second chapter, we learned about lactic bacteria and their various types and their uses in dairy industries such as cheese and yogurt and in fermentation processes. where the isolation and characterization of lactic acid bacteria present in raw and fermented camel milk is essential in the development of functional products derived from camel milk. Lactic bacteria included in the fermented milk strengthen pathogenic-targeting antibacterial activity. while starter lactic acid bacteria and non-starter lactic acid bacteria interact from the early stages of manufacture to the cheese ripening process, and combinations of starter bacteria with mesophilic *Lactobacillus* spp. Are common tools used to accelerate and conduct cheese ripening. The fermentation of milk by a species of bacteria known as lactic acid bacteria results in the dairy product known as yogurt.

In the third chapter, dealt with the various types of dairy camel products such as Fermented camel milk, yogurt, cheese of all kinds, milk powder, butter, ice cream and chocolate. Fermentation is one of the oldest ways to consume camel milk. Each camel country has its own traditional fermented milk in terms of microbiological, physical and chemical characteristics, in addition to the fermentation method that is

customary in that region. However, not all camel milk products yielded satisfactory results. Cheese made from camel milk has processing problems and is of lower quality if produced using the same technology as dairy products made from cow milk. The camel milk yogurt industry has a problem with the texture, as the product looks sticky and unpleasant in the end. Researchers are trying to find ways to improve the quality of these products, such as combining camel milk with cow or goat milk. While products such as ice cream and chocolate are still being tested and are not available in all markets.

In the last chapter, We found that Camel milk has a lot of health benefits, including interesting medical. Many studies have reported that camel milk has potential therapeutic properties such as antidiabetic, wound healing in diabetic patients, hepatitis C infection curing, hypoallergenic effect, and treatment for skin conditions . It has also been proven as a good alternative for people with cow milk allergy and as a therapeutic agent to reduce the harmful effects of exposure to toxins. Most of these properties are attributed to the unique characteristics of camel milk proteins. Most of the research on the therapeutic effects is carried out at the in vitro level and therefore requires in vivo models to confirm them further and why not in the near future we could witness the development of camel milk based therapies.

After examining 112 references, we noticed that camel milk has received global attention due to the nutritional value it contains, as well as its therapeutic and preventive health benefits. Studies are still going on camel milk and its products.



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