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Camel Milk Product Processing Characteristics and Bioactive Based Infant Formula: A Review

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Abstract

The processing of camel dairy products processing technologies has seen notable advancements in recent years. Heat treatment, milk coagulation enzyme, spry-drying were among the camel dairy product technologies. Due to the casein micelles structure and low k-casein content, cheese processing from camel milk was challenged which result in the formation of soft and weak gel structures. Camel chymosin solves much of cheese processing challenge, but plant extracted coagulant identification, application and its significance in camel milk cheese processing was not well addressed. The concentration of camel milk proteins was higher than that of other bioactive peptides made from milk proteins. Specifically whey protein derived from camel milk has special physiological, nutritional, and technological properties that are advantageous in the infant milk formulation. Therefore, due to its protein profile (lower concentration of α-casein, higher β-casein, higher percentage of whey protein, and absence of beta-lactoglobulin), camel milk has a better similarity to human milk. Unfortunately till now camel based infant formula was not produced. It is possible to process infant milk formula into dry powder, in the form of liquid, and liquid ready-to-feed forms (RTF).To concentrate or standardize the nutrient required for infant formulation mainly whey protein, vitamin and minerals membrane filtration technology is recommended. To produce milk powder from camel milk spry-drying technology is recommended. Anti-microbial, immune-modulating, antioxidant, vitamin and mineral content as well as hypoallergenicity of camel milk indicate its suitability to formulate bioactive based infant formula.

Keywords

Bioactive, Camel Milk, Infant Formula, Processing Technology

1. Introduction

Infant formula's was derived from dairy animals, specifically cow milk, which was a common source for infant formula [1]. According to European Union (EU) law, infant formula is "food intended for use by infants during the first months of life and, meets by itself, the nutritional requirements of newborns until the introduction of appropriate complementary feeding"[2].One of the foods with naturally occurring bioactive components are the dairy products, whose nutritional benefits have been proven by science [3]. Camel milk has recently generated a lot of interest among dairy species due to its exceptional nutritional attributes, bioactive substance, and abundance in vitamins and minerals [4]. However, compared to bovine, it has not received as much attention because to its low production and processing challenges [5].

Additionally, preparing dried camel milk has only been the subject of a small number of investigations [6]. The bioactive compounds obtained from dairy have primarily been studied in relation to bovine milk [7] and there was few information available on the role of camel milk's bioactive compounds which contribute for the production of human food [8]. There is a significant difference in composition between human milk and cow milk based infant formulas that has

been highlighted by the finer details [9]. Therefore, this paper was targeted to assess camel dairy product technology and bioactive based infant formulation.

2. Camel Milk Production and Processing Characteristics

The dairy products that came from less common dairy animals like camelids were not considered to be as crucial for market as those from bovine [10]. The market for camel milk products, in contrast, has increased as more people are becoming aware of its physiochemical properties, health benefits, and nutritional worth. However, between 2018 and 2022, the global market for camel milk will expand by 7% [11]. The global market for camel milk is anticipated to reach $10.07 billion by 2027, growing at an 8% annual [12]. Additionally, its global production increased annually at a rate of more than 8% between 2009 and 2019 [13].

2.1 Camel Dairy Product Technology

Camel milk is more challenging to processes into various type of dairy products than other milks [14]. Camel milk product processing requires different commercial processing methods or technological approaches than cow milk does [15]. As a result, the product's overall quality, including its digestibility and nutrient composition, might be impacted by the processing methods used. However, most camel milk processing facilities adopted the same technology used for cow milk, which creates processing challenges [16]. With some technical modifications during manufacturing process and modern technology; camel milk has been successfully converted into a variety of dairy products, including heat-treated fluid milk, fermented milk products, several varieties of cheese, butter, and ice cream [17]. Tiviski in Mauritania, Camelicious in Dubai, Berwako and Addis Kidan Milk processing enterprises in Ethiopia and Vital Camel Milk Ltd in Kenya were among the nations that process camel milk products [18].

2.2 Protein Fraction of Camel Milk

Among various nutrients, protein is one of the most functionally important nutrients [19]. Human milk contains almost three times less protein than doe's milk from cows.Caseins can play an important biological function after being hydrolyzed by different proteases [20]. In camel milk, casein (CN), which makes up 52–87% of the total protein, is the predominant protein [21]. Additionally, it contain 22% αs1-CN and 9.5% αs2-CN, compared to 38% αs1-CN and 10% αs2-CN in cow milk [22].Human milk is protein composition (whey to casein) proportion is ~60:40 [23], beta-casein to alpha-casein percentage is also higher[24]. In infant formula, faster milk protein digestion is caused by a lower casein-to-whey protein ratio (i.e., a higher proportion of whey proteins) [25]. Casein from camel milk has a lower ratio of β-CN to *k*-CN than casein from cow milk. The enzymatic coagulation of casein micelles in camel milk is impacted by this low ratio. Beta casein found in camel milk has more digestible and less allergenic casein [26]. Furthermore, due to the high concentration of β-CN, it is more susceptible to hydrolysis by chymotrypsin and pepsin, which increases its digestibility[27]. Bioactive peptides are created by β-CN hydrolysis, and amino acids with antioxidant characteristics such phenylalanine and tryptophan are also released [28].

Amino Acid Composition of Camel Milk

Amino Acid (AA) profile has been reported a problem in cow milk-based infant formulation[29]. Lysine is the limiting amino acid in camel milk, whereas cysteine and methionine are in buffalo and cow milk. It's noteworthy to notice that camel milk includes more methionine, valine, phenylalanine, arginine, and leucine than cow milk[30]. Camel caseins have slightly more proline (12.0) than cow caseins (9.9) [31]. In comparison to caseins from cow milk, camel caseins have a greater proline content, which could cause a more dramatic instability of secondary structures.

The enzyme cystathio-nase, which changes methionine into cystine, is only present in small amounts in the liver and brain of newborn humans (the fetus and preterm infant are completely lacking this enzyme). Cysteine is crucial for the growth of the central nervous system [32]. Because of its high methionine concentration, camel milk has a higher cystine:methionine ratio (0.38) than cow milk (0.36) [33]. Since infants have a limited capacity to metabolize these amino acids, the content of phenylalanine in cow milk on infant formula is an issue because it can accumulate and lead to phenylalanine ketone urea (PKU babies) [34].

Compared to cow milk, camel milk's whey proteins make up 23% of the total proteins [35]. Whey provides significant functional protein properties, including energy and vital amino acids, as well as physical and functional qualities for use in food preparation, such as foam stability, gel formation, and water retention[36]. The main whey protein in camel milk is alpha-lactalbumin, which is more hydrolysable (digestible) with trypsin and chymotrypsin enzymes than cow.

2.3 Bioactive Property of Camel Milk

In addition to being a source of nutrition, milk can deliver unusual molecules with bioactive properties that support the growth and well-being of newborns [37]. The milk from camel has various bioactive ingredients, showing special

properties that make it distinct and unique. It contains significantly higher bioactive compound than sheep, goat, cow and buffalo milk [38]. Compounds that are either naturally present in food or ones that are created and/or synthesized during food processing that may have physiological and biochemical functions when consumed are referred to as "bioactive components." [39].

It is well recognized that bioactive substances included in foods are transported by protein-based particles [40], which can play a vital roles in human food manufacturing [41]. Other bioactive peptides may be produced in addition to native protective proteins by the hydrolysis (or breakdown) of milk proteins (casein and whey) by proteolytic enzymes [42]. They provide vital biological functions such as possessing antibacterial, antioxidant, immunomodulatory, and mineral-carrying properties [43].

2.3.1 Immunogenic Property

Infant passive immunity is primarily mediated by immunoglobulins (IgG), which are the predominant immunoglobulin in camel's milk[44]. According to the study, a key nutritional physiological requirement for infant formulation it may be the lack of immunological similarity between camel's milk and cow's milk proteins[45]. According to the study's findings, camel milk has the greatest concentration of total IgG (1.64 mg/ mL), compared to cow, buffalo, goat, sheep, and human milk, which have respective levels of 0.67, 0.63, 0.70, 0.55, and 0.86[46].There is evidence that camelids produce an entirely new class of immunoglobulins that are fundamentally distinct from all other known antibodies [47]. It provides cameloid IgGs with an advantage over larger immunoglobulins containing milk by allowing easy and quick targeting of the antigen and subsequent penetration of a disease-causing bacteria [48].

2.3.2 Antioxidant activity

Several research investigated the possibility of using camel's milk as a protein substrate to produce bioactive protein hydrolysates with antioxidant properties [49]. Amino acid sequences, peptide bonds, or structural conformation arrangements have all been linked to the antioxidant activity of peptides. The type of protease, peptide structure, level of hydrolysis, and peptide concentration are all factors that determine the antioxidant activity of bioactive peptides. As camel milk casein is higher in β-CN (65%), it produces radical scavenging peptides during gastro-intestinal digestion which is the best source of antioxidant peptides. In fact, compared to other camel caseins, camel beta-CN has the highest hydrophobicity. Moreover after being hydrolyzed with chymotrypsin, it demonstrated strong antioxidant action [50].Addition of α-chymotrypsin can produce hydrolysates with significantly higher antioxidant property [51]. When compared to cow's milk, the globular protein alpha-lactalbumin (α-La), which can be extracted from whey protein isolates (WPI), is very good source of antioxidant bioactivities [52].

2.3.3 Antimicrobial activity

Food manufacturers prefer to use more natural sources of antimicrobial agents in the production process due to the negative effects of synthetic antimicrobial agents on both human health and the environment impact [53]. A multifunctional bioactive molecule with a crucial involvement in numerous significant physiological pathways is the foundation of this natural antibacterial property[54], which inhibits the growth of iron-dependent bacteria [55]. Once digested, camel milk proteins release different bioactive peptides which have antimicrobial property [56]. Camel milk lactoferrin acts as a multi-functional protein including the strong pathological effects [57]. The concentration of camel milk lactoferrin ~0.02-2.1 gram/L, which is higher than cow milk (0.14 gram/L) [58].

2.4 Bioactive Lipid Components

Milk lipids provide necessary fatty acids, which act as a solvent for the fat-soluble vitamins, and also serve as energy source. As compared to cow milk, camel milk has a lower fat content [59]. The milk fat globule membrane (MFGM), a layer of a surface-active material, covers the milk fat globules and plays a variety of nutritional and physiological activities [60]. There have already been reports of the typical size of fat globules of camel, cow, buffalo, sheep, and goat milk [61]. Since camel milk fat globules size is smaller with a greater surface area than others, which results in quick digested by gastrointestinal lipases [62]. Monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) are more prevalent in human milk fat than saturated fatty acids (SFAs) [63]. Additionally, cow milk has a larger percentage of saturated fatty acids (69.9%) than camel milk (67.7%) [64]. Camel milk has 84.5% long-chain fatty acids compared to cow milk's 72.18% and human milk's 80.2% [65]. Furthermore, oleic acid (24.5%) and palmitic acid (29.1%) are the two main fatty acids in camel milk[66]. While in cow milk, linoleic (C18:2) and Linolenic (C18:3) were higher [67].

2.5 Hypoallergenic Properties of Camel Milk

Cow milk allergy (CMA) is a scientific term used which indicates an inappropriate immune response to cow milk proteins that may result from the interaction of one or more immune systems with one or more milk proteins. Casein fractions (particularly αs2- and αs1-) and beta-lactoglobulin were proteins that were identified in cow milk that trigger

allergic responses [68]. Researchers report that around 2-6% of infants possess allergenicity for CMA[69]. As an advantage camel milk has a low percentage of α-casein and it lacks β-lactoglobulin, which reduces the possibility of allergenicity [70]. Since camel milk based infant formula can bean alternative solution for children who are allergic to cow milk. The absence of immunological similarity between camel and cow milk proteins should be the other parameter which should be considered in preparation of bioactive based infant formulation [71].

2.6 Bioactive Based Infant Formula

Generally the composition or constituents in infant formula are planned based on the stage of individuals need to satisfy the nutritional requirements. The stage 1 of IF products (designed for infants 0 to 6 months) often has the highest protein and carbohydrate content[72]. Infant formula prepared from camel milk that is bioactive-based has not yet been studied. A few attempts were made, including the formulation, characterization, and comparison of commercial and camel milk-based infant formula [73]. Additionally, the impact of varying levels of fortification with casein and whey protein on IF based on camel milk was investigated. Infant formula can be produced using a variety of processing techniques[74]. It can be produced as concentrated liquids, powders, or ready-to-feed productstypes. In cow milk based infant formula based on processing cost, availability and customers preference the researchers reported as ready to feed, is the most convenient than others[75].

Membrane filtration technology is the other important techniques applied for standardization of nutrient composition. It is more preferred when we need to process IF with a minimum protein denaturation and vitamin and mineral loss during infant formulation [76]. The most common techniques used in membrane filtration technology includes; Microfiltration, Ultrafiltration, Nano filtration as well as Reverse osmosis [77]. This technology uses the concept of separation, concentration differences as a driving force to separate large and small particles in a solution. Reverse osmosis has been used to concentrate whey proteins during the production of infant formula from the methods previously mentioned [78]. However, macromolecules like proteins which are found in the milk can be concentrated or standardized by using ultrafiltration [79].

The conversion of IF into easily manageable and shelf-stable products like powders is necessary after concentration or standardization of the nutrient after membrane filtration [80].In fact the application of different level of heat treatment can have its own impact on the processed product quality. During infant formula manufacturing from cow milk based IF with high pressure processing (HPP) under 300-600 MPa at roughly 20 to 40^{O}C, UHT application can causes the nutritional profile of Ready to feed IF to deteriorate, especially vitamin A, B, and D, along with protein denaturation. On the other hand the maximum concentration of bioactive components was achieved after HTST pasteurisation (72°C for 15 sec).Even though the scientifically approved evidence which pasteurization is suitable forconcentrated or standardized milk nutrient to make it powder in bioactive based infant formula derived from camel milk is limited.

3. Conclusion

Considerable progress has been observed in the development of camel milk technology. It was due to special bioactive components of the product and its beneficial health impact. Regarding to mineral and vitamin content, it is rich in vitamins C, calcium and iron than other dairy species. Bioactive peptidesinclude lactoferrin, lactoperoxidase; lysozyme has antimicrobial activities. The higher immunoglobulin concentration have significant role in immune development. By having higher whey to casein ratio, absence of beta-lactoglobulin, lower α-casein content, and being hypoallergenic nature were an indicator of similarity of camel milk with human milk property. An IF made from camel milk had a higher levels of radical scavenging property, which might be markedly higher values of lactoferrin than those found in conventional infant formula. Additionally, camel milk is superior to cow milk in terms of anti-inflammatory properties, indicating that it may be a good alternative for the manufacture of IF. Lastly, the reviewed literature indicates that camel milk is more suitable to produce bioactive based infant formula.

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