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Comprehensive dynamic changes in milk composition: insights from lactational stages in dairy goats

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ABSTRACT

Goat milk has long been a significant component of human nutrition owing to its comparative nutritional values with human milk, softer curds, and higher fat content. However, specific dietary deficiencies limit their suitability for infants; in addition, there are observed variations in protein, fat, and enzymes between goat and cow milk which have prompted investigations into somatic cell counts, which naturally tend to be higher in goat milk unlike cow milk. The production and composition of milk is being influenced by a range of factors, with the stage of lactation being particularly critical. As lactation progresses, there is a decrease in protein, lactose, fat, and total solids, accompanied by a decline in milk output. Therefore, an understanding of these physiological shifts is vital for dairy goat nutrition and supporting management decision-making systems to optimize goat dairy band production. This review delves into the composition of goat milk, elucidates its structural components, and identifies the functional groups present at different lactation stages. This research contributed knowledge to enhance understanding of goat milk properties across the lactation cycle and potential impact of physiological stages on milk quality.

INTRODUCTION

In the 1960s, the goat and its dairy products, once regarded as the "poor man's cow," started to capture interest in the United States. This newfound attention stemmed from goat milk's perceived health benefits and nutritional value and its derivatives. Renowned for its easy digestibility and purportedly lower allergenic properties than cow milk, goat milk has been hailed as a nutraceutical for several decades (Clark & García, 2017). Despite early reports being largely anecdotal, the recognition of its potential health advantages has continued to grow (Bläuer et al., 2022). Animal products play a significant role in human diets, and goats, among the first domestic animals, serve as an important source of animal foods, especially in the form of milk and dairy products. Goat milk is trendy for people with digestive disorders or allergies. It boasts higher percentages of carbohydrates, fats, and proteins than cow's milk (Al-Kaisy et al., 2023) and notably, it has more short- and medium-chain fatty acids (Amores & Virto, 2019). Milk's composition and fatty acid content play a substantial role in determining its nutritional value and quality, influencing both the mammary gland's status and the health of goat offspring (Yakan et al., 2021).

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These factors are pivotal in effective animal management systems. To better understand the intricate relationships between the fatty acid components of milk and the more easily determined composition parameters, efforts have been made to establish connections (García et al., 2014). While simple correlation coefficients are commonly used for this purpose, they may fall short in uncovering latent or indirect relationships. To address this, multivariate statistical methods such as Canonical Correlation Analysis CCA) prove effective. CCA elucidates relationships by calculating linear combinations between two datasets, offering insights into structural and spatial inferences by simultaneously managing both datasets. This approach proves especially valuable in comprehensively explaining the complex interplay of factors influencing goat milk composition and fatty acid components (El-Tarabany et al., 2019; Ibrahim et al., 2022; Özkan & Yakan, 2020).

Because they offer so many benefits, goats have long been the primary source of milk and meat in poor nations. These consist of affordable feeding needs, a short gestation time, easy handling, a controllable housing system, and the capacity to ensure a consistent provision of milk (Prosser, 2021). The global production of goat milk is on the rise, with the majority being utilized either in its raw form or processed into various dairy products such as cheese and yogurt (Miller & Lu, 2019). Goat milk's important components—protein, lipids, carbs, vitamins, and minerals—made it the product of choice for manufacturers to meet the demands of the medical industry as well as the market for gourmet foods. Goat milk contains a higher proportion of medium-chain fatty acids and conjugated linoleic acid (CLA) in its fat composition. These components contribute to the distinctive goaty flavor and cheese-like aroma of the milk. Additionally, they are associated with the milk's potential anti-carcinogenic and anti-atherogenic properties (Mohsin et al., 2019). Goat milk offers several significant nutritional benefits for human consumption, including its high digestibility, low inflammatory properties, and minimal allergenic potential. Even more intriguingly, goat milk has shown promise in enhancing various physiological processes, especially in young children and the elderly (İskender et al., 2018; Sepe & Argüello, 2019).

It has been established that medium chain length fatty acids, alternatively termed medium chain triglycerides (MCT), are abundant in goat milk and are special lipids with unique health benefits. These benefits are particularly notable in conditions such as intestinal resection, coronary bypass, chyluria, steatorrhea, hyperlipoproteinemia, and childhood epilepsy (Zailan & Yaakub, 2018). Additionally, MCT dissolves cholesterol gallstones, prevents or restricts the buildup of cholesterol, and supports a baby's natural development (Zailan & Yaakub, 2018). Goat milk exhibits superior digestibility compared to cow milk due to its smaller fat globules and shorter fatty acids (Hodgkinson et al., 2018). Health-promoting substances found in goat milk include oligosaccharides, conjugated linoleic acids, and bioactive peptides. These characteristics also facilitate the manufacturing and marketing of dairy products made from goats (Verruck et al., 2019b). Most people who have gastrointestinal issues or are intolerant to cow's milk drink goat milk (Pulina et al., 2018). According to reports, goat milk is more popular in Asia since it tastes and feels different than cow milk and has more minerals (Ibrahim & Tajuddin, 2021).

Compared to other livestock industries, the goat dairy sector is still small-scale in Malaysia (Jaafar et al., 2018), due to the absence of a native dairy goat breed capable of high milk yields in Malaysia, the government imported Saanen goats to enhance the goat milk sector. This breed was chosen for its adaptability to various environmental conditions and its suitability for high milk production. To fulfill the demands of the market and achieve optimal production, meeting both milk and composition requirements is crucial in the dairy goat sector (Ibrahim & Tajuddin, 2021). Goat milk production and composition are influenced by a range of factors such as diet, breed, individuals, parity, season, feeding, management, environmental conditions, locality, lactation stage, and udder health status. Neglecting these factors can also result in changes to the flavor and color of the milk (Li et al., 2022).

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The review investigates the composition and structure of goat milk, highlighting the presence of functional groups at various lactation stages. The aim is to enhance comprehension of goat milk properties throughout the lactational cycle and their potential impact on milk quality. This knowledge can be leveraged to enhance both milk production and quality standards.

Goat milk yield and lactation stage

The form of the lactation curve plays a crucial role in determining the amount of milk generated. Important elements of the lactation pattern comprise the apex of milk production, indicating the highest yield of milk throughout lactation, and lactation persistency, which indicates the capacity of animals to sustain a steady level of milk production following the lactation peak (Auldist et al., 2007; Cannas et al., 2002). Research undertaken to investigate the milk yield and composition of Damascus Does raise in Sudan demonstrated that various phases of lactation influenced both the quantity and composition of their milk. The chemical makeup of the milk declined with the advancement of lactation stages (Mahmoud et al., 2014). The reduction in routine milk production following the peak period can be attributed to the progression of lactation, as elucidated by Patbandha et al., 2015 and Strzałkowska et al., 2009. A study by K. Peter (1995) illustrate that three Egyptian goat breeds exhibited good persistence in their milk production (Peters, 1995). Notably, Othman & Mahfouz (2016) showed a slightly higher output during the first half of lactation. There were differences in milk production between the first and third lactations, as well as between the second and third lactations, as indicated by Cismaş, Acatincăi, et al. (2012). Across various breeds, the percentages of fat, protein, lactose, ash, total solids, and solids nonfat increased as lactation progressed, as reported by Singh et al. (2014).

The form of the lactation curve plays a crucial role in determining the amount of milk generated. Important elements of the lactation pattern comprise the apex of milk production, indicating the highest yield of milk throughout lactation, and lactation persistency, which indicates the capacity of animals to sustain a steady level of milk production following the lactation peak (Auldist, O'brien, Cole, Macmillan, & Grainger, 2007; Cannas, Nudda, & Pulina, 2002). Research undertaken to investigate the milk yield and composition of Damascus Does raised in Sudan demonstrated that various phases of lactation influenced both the quantity and composition of their milk. The chemical makeup of the milk declined with the advancement of lactation stages (N. Mahmoud, El Zubeir, & Fadlelmoula, 2014). The reduction in routine milk production following the peak period can be attributed to the progression of lactation, as elucidated by Patbandha et al. (2015) and Strzałkowska et al. (2009). A study by K. Peter 1995 illustrates that three Egyptian goat breeds exhibited good persistence in their milk production (Peters, 1995). Notably, Othman & Mahfouz (2016) showed a slightly higher output during the first half of lactation. There were differences in milk production between the first and third lactations, as well as between the second and third lactations, as indicated by Cismaş et al. (2012). Across various breeds, the percentages of fat, protein, lactose, ash, total solids, and solids nonfat increased as lactation progressed, as reported by Singh, Sharma, Kumar, & Chauhan (2014).

Despite varied raising practices, the phase of lactation held a significant impact on goat milk quality (Singh et al., 2014). Protein, lactose, and solid nonfat (SNF) had minimal amounts during early lactation and subsequently grew dramatically as lactation progressed toward its conclusion (Darwesh et al., 2013b). Aganga *et al* (2002) found that minerals changed during the lactation period in their study of the influence of lactation on the composition of Tshwane goats. Ehoche & Buvanendran (1983) noticed in the Red Sokoto goat a trend of daily milk outputs dramatically increasing to a maximum within two weeks and then dropping to the end of lactation. The lactation phase had a considerable impact on milk composition, with fat and protein contents inversely connected with milk output and lactose contents favorably correlated. The observed milk supply trend might be attributed to epithelial cell growth in the milk gland, particularly during the initial stages of

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lactation. According to Moya et al. (2014) and Sikiru & Makinde (2018), mammary cell proliferation increases during early lactation and decreases as breastfeeding proceeds. As per Stojević et al. (2005), in the initial phases of lactation, high-yield dairy does experience notable physiological and biochemical changes in their liver to counteract the adverse effects of negative energy balance (NEB). The production of proteins, lactose, fat, and dry matter is linked to the metabolic activity of the liver. Blood serum markers provide valuable insights into the nutritional status and physiological health of dairy does in relation to their age and lactation stage. The biochemical characteristics of blood are requisite indicators of the metabolic processes in lactating animals, reflecting the functioning of their liver, as emphasized by Karapehlivan et al. (2007). Throughout lactation, approximately 80% of circulating metabolites in the bloodstream are utilized by mammary gland secretory cells for the synthesis of milk. This allocation is contingent on the rate at which building blocks for milk components, such as free amino acids, glucose, and fatty acids, are absorbed into the cells.

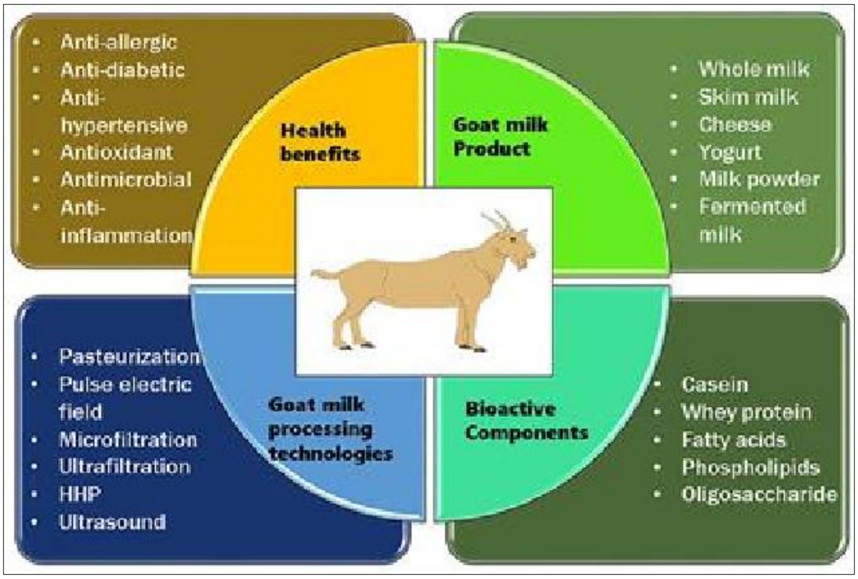

Fig. 1. Processing, bioactive compounds, & health benefits of goat milk copyright permission from Frontier 2021 (Nayik et al., 2021).

The quantity of mammary secretory cells and their metabolic functioning, both of which change during lactation, are determining factors for milk production, as explained by Stelwagen (2001). During this process, lipogenesis is inhibited, and there is an increase in the release of fatty acids. This increase is facilitated by the stimulation of norepinephrine and adrenaline, leading to heightened lipase activity in the milk gland. Ultimately, this supports the synthesis of milk fat, as observed in the research by Nazifi et al. (2002). Lactating goats undergo an increase in total protein content in serum as lactation progresses due to protein catabolism for milk production (Krajnicakova et al., 2003). Throughout lactation, goat milk's content varies greatly; the biggest alterations occur soon after the lactation begins. The first secretion extracted from the gland is called colostrum. The discharge content is progressively identical to fully grown milk. There is demonstration that because goats secrete more at this stage of lactation, efficient milking is essential for them (Salama et al., 2003).

A study conducted by Kuchtík et al. (2008b), it was clearly shown that the stage of lactation exerted a notably influential effect on the levels of various milk components. Specifically, total solids, nonfat solids, fat, protein, and casein levels experienced significant increases as lactation

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advanced. The percentages of crude protein, fat, and lactose content exhibited significant variations across the four lactation phases, which included colostrum, early, mid, and late stages. Conversely, changes in total solids, pH, and ash content remained unaffected by the phase of lactation, as observed in the study by Zahraddeen et al. (2007). Notably, milk from the early and late lactation stages contained significantly higher levels of various milk components, as pointed out by Mestawet et al. (2012b). Cows that produced high quantities of milk initially and maintained consistently high yields throughout lactation were more vulnerable to udder ailments later. This vulnerability extended to cows with sustained high milk output but decreased lactation persistence, making them prone to udder diseases even after the lactation peak. However, there was no distinction in the total milk production between groups with and without udder disorders at any stage. This indicates that cows unaffected by udder issues had more consistent milk production curves compared to those experiencing udder ailments, despite achieving similar levels of lactation (Yamazaki et al., 2009).

Overview of dairy goat milk composition

The worldwide goat population has surpassed one billion individuals. Due to increased demand, the goat count maintained for milk production is also increasing. Although Asia accounts for the majority of worldwide goat milk output and consumption, a worldwide look at the dairy goat industry shows critical lessons for developing effective modern dairy goat enterprises (Miller & Lu, 2019). Europe, particularly France, has the best-organized goat milk market. The European goat sector is focused on dairy output, primarily for the manufacturing of industrial cheese, while also aiding conventional on-farm production. The government has a significant role in sanitary regulation, research, extension, and support for local producer groups and markets, as well as ensuring safety and quality. Despite this, manufacturers remain exposed to market changes due to increased consumer demand, high pricing, and climate change, new dairy goat businesses are sprouting up in nations with no historical history of goat milk production, such as China, the United States, and New Zealand (Miller & Lu, 2019).

Dairy goat farming succeeds across countries despite differences in regulations, commerce, and management approaches. The key to this success is ensuring farmers can connect with markets and have the knowledge to raise their goats and care for the environment responsibly. Strong producer groups, access to technical support, and laws that allow everyone to participate in this growing market are all essential (Miller & Lu, 2019). The International Goat Association (IGA) has represented the goat industry internationally since 1982. Through conferences, academic journals like Small Ruminant Research, and social media, the IGA has advanced goat knowledge and practice. By collaborating with researchers, producers, and policymakers to exchange knowledge and experiences, the industry will be able to reach its full potential. With the mission to advance goat research and development for the benefit of mankind, reduce poverty, foster prosperity, and enhance the quality of life, IGA is the sole organization that promotes the goat industry globally (MORU et al., 2023). It is an international network of people and institutions that links research, production, processing, and marketing; exchanges expertise, best practices, and knowledge; supports the production of goats in a way that is socially, environmentally, and commercially viable; and encourages local, regional, and global activities from a variety of viewpoints (Miller & Lu, 2019; MORU et al., 2023). Since the 1960s, the number of goats worldwide has grown significantly due to changes in human health and dietary choices, as well as climatic changes that has restricted the areas where cattle are raised.

The worldwide goat herd surpassed one billion head in 2013, an increase of more than 34% since 2000 (ISLAND, 2005). During the same period, the sheep population increased by just 10%, while the world cattle population stayed relatively steady at around one billion head (Rotz et al., 2019). Asia possesses a substantial share, 60% of the global goat population. China, India, Pakistan, and Bangladesh are prominent contributors to this concentration. While meat production remains the

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primary source of revenue from goats globally, there is a simultaneous rise in goat milk production and consumption (Miller & Lu, 2019). Milk derivatives are in high demand in tropical developing nations due to the constantly rising human population. The increased need can be addressed by expanding the number of ruminant animals, as indicated by Getaneh et al. (2016). Goats and small ruminants in general will play a leading role in meeting this requirement. In many tropical regions, goats are an important source of milk, and in many developing countries, they make a significant nutritional contribution (Miller & Lu, 2019). One of goat milk's most important nutritional benefits to humans is the calcium and phosphate it offers. Like cow milk, goat milk contains around 1.2 g of calcium and 1 g of phosphate per liter. Compared to cow's milk, human milk only contains one-fourth the calcium and one-sixth the phosphate. Therefore, the human baby receives a large excess of calcium and phosphorus from goat milk in relation to energy, and the human child absorbs both of these nutrients from the milk (Getaneh et al., 2016; Ribeiro & Ribeiro, 2010). Goat milk soft curd has potential benefits for adult humans with gastrointestinal diseases and ulcers (Park, 1994; Pirisi et al., 2007). The strong buffering capacity of goat milk may help with stomach ulcer therapy (Park, 1994). Goat milk has been suggested as a substitute for cow milk for those who are allergic to it. Patients with cow milk protein allergies can accept goat milk 40–100% of the time (Anthes & De Schutter, 2018; FAO, 2018), except for lactose, which is low, the gross composition of goat milk is higher than that of bovine milk. Fat globules are smaller, which is one of the reasons behind this milk's ease of digestion. Its products contain lots of protein, fat, phosphate, and calcium. Diet, breed, habitat, and management all influence its makeup (Malau-Aduli et al., 2001). Goat's milk is the most complete food known to man, as well as the most suitable and nourishing natural diet. It is so healthy that it may be used as a meal replacement. It is also popular because of its low-fat level and capacity to neutralize acids and toxins in the body. Production of goat milk varies from cow or human milk in that it is more digestible, has a distinct alkalinity, has a greater buffering capacity, and has therapeutic properties in medicine and human nutrition. The nutritional and physiological advantages of goat milk are linked to a variety of medical conditions, the most prominent of which are food allergies, and it may also be used as a replacement for individuals who are allergic to cow milk (Morgan et al., 2012). Natural homogenization of goat milk is far superior to mechanically homogenized cow milk in terms of human health. It appears that mechanically breaking up fat globules permits an enzyme related to milk fat known as xanthine oxidase to become free and penetrate the intestinal wall. Once xanthine oxidase enters the circulation from the intestinal wall, it can cause scarring in the heart and arteries, which may prompt the body to release cholesterol into the blood to deposit a protective fatty substance over the damaged portions. Arteriosclerosis can result from this. It should be emphasized that this effect does not occur in raw (unhomogenized) cow milk. This enzyme is generally eliminated from the body without considerable absorption in unhomogenized milk (Getaneh et al., 2016).

Nutrient composition of milk: In terms of composition, goat milk is like cow milk. 12.2% total solids, or 3.8% fat, 3.5% protein, 4.1% lactose, and 0.8% ash, make up caprine milk on average. Compared to cow milk, it has less lactose and more fat, protein, and ash (Park, 2010).

Fats content in milk: The fats in milk, known as butterfat, are suspended globules that are visible under a low-power microscope. The majority of goat's milk's unique qualities come from its lipid content (Getaneh et al., 2016). Goat milk can include anything from 2.45 to 7.76% fat in it. According to Ibrahim et al. (2022) and Park (2010), goat milk fat comprises 97–99% free lipids, of which approximately 97% are triglycerides, and 1-3% bound lipids, of which approximately 47% are neutral and 53% are polar lipids. Goat's milk seems to give a noticeable advantage over cow's milk in terms of cholesterol; cow's milk normally has 14 to 17 mg of cholesterol per 100 grams of milk, but goat's milk typically has 11 to 25 mg (Auld et al., 2000).

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Protein content in milk: Casein and whey protein make up the two types of milk protein. In comparison to cow's milk, goat milk has about comparable levels of k-casein fractions, larger amounts of β-casein fractions, and less αs-casein. αs1-casein is the main protein in cow milk, whereas β casein is the main protein in goat milk. αs1-casein is also present in equivalent amounts in goat milk, however, the quantity and genetic polymorphisms vary throughout goat breeds (Ibrahim et al., 2018; Lad et al., 2017). Whey proteins are refined proteins that have been isolated from casein; they can be used for wound healing, weight loss, baby health, and other purposes. Whey proteins come in varying quantities. It is one of the best proteins for people of all ages and keeps them healthy, especially when combined with a nutritious diet (Foegeding et al., 2002; Gupta et al., 2016).

Lactose content in milk: The main carbohydrate in milk is lactose, which is the only disaccharide sugar there is. It is made up of one glucose molecule joined to one galactose molecule. Goat milk contains between 4.1% and 5.2% lactose (AbdAlmageed, 2009). Goat milk also contains minor amounts of oligosaccharides, glycopeptides, glycoproteins, and nucleotides. Due to their prebiotic and anti-infective qualities, milk oligosaccharides are advantageous for human nutrition (Lara-Villoslada et al., 2006).

Mineral content in milk: Goat milk has been found to contain higher amounts of minerals when compared to cow milk, with some minerals showing a particularly notable difference in concentration. Goat milk provides a great amount of calcium and phosphorus (Belewu & Aiyegbusi, 2002). The major and trace minerals in goat milk include Ca, Na, Mg, P, K, Zn, Mn, Se, Co, Cu, and Fe, respectively. Goat milk has natural mineral nutrition that brings excellent health benefits (Haenlein, 2002). Goat milk contains about 134 mg Ca and 141 mg P/100 g. Human milk contains only one-fourth to one-sixth of these mineral amounts. Goat milk has higher calcium, phosphorus, potassium, magnesium, and chlorine, but lower sodium and Sulphur contents, than cow milk (Park, 2010).

Vitamins content in milk: The amount of vitamin A in goat milk is higher than in cow milk. Caprine milk is whiter compared to bovine milk because goats convert all β-carotene in the milk to vitamin A. Goat milk has adequate amounts of vitamin A and niacin, and an excess of thiamine, riboflavin, and pantothenate (Park, 2010). Goat milk contains a similar amount of vitamin A as human milk. Vitamin A is important for both innate and adaptive immune responses, including cell-mediated immunity and antibody responses. Vitamin C is a well-known water-soluble antioxidant that is found in greater amounts in goat milk than in cow milk. This vitamin has been shown to affect many aspects of the immune system including the regulation of immunity via antiviral and antioxidant properties (Lad et al., 2017). Goat milk is also a good source of vitamins D and E. Goat milk has low levels of folate (Park, 2017). In terms of composition, goat milk is similar to cow milk. On average, caprine milk consists of 12.2% total solids, including 3.8% fat, 3.5% protein, 4.1% lactose, and 0.8% ash. Goat milk has less lactose but more fat, protein, and ash compared to cow milk (Y.W.J.E. et al., 2010).

Functional properties of goat milk: Goat milk has both probiotic and prebiotic qualities. According to (Gibson, Hutkins, Sanders, Prescott, Reimer, Salminen, Scott, Stanton, Swanson, Cani, et al., 2017), a prebiotic is defined as a selectively fermentable substance that causes certain alterations in the makeup and activity of the gut microbiota, improving the host's health. Goat milk is a desirable natural source of oligosaccharides utilized in human nutrition and has a comparatively high content of prebiotics when compared to the milk of other ruminants (Verruck et al., 2019b). Living microorganisms that help the host's health when present in sufficient quantities are referred to as probiotics (Hill et al., 2014). According to Ranadheera et al. (2018b), taking probiotics can help balance the microbiota in the gut, improve lactose metabolism, strengthen the immune system, and

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have anticarcinogenic benefits. Among dairy products that do not come from cows, goat's milk is the main source of probiotics. Goat's milk has physical-chemical characteristics that help bacteria survive over time, including a suitable pH, adequate buffering capacity, and a high nutritional content (Ranadheera et al., 2018b). Moreover, it has been frequently utilized to separate bacteria with possible probiotic properties from both raw goat milk and conventional goat milk yogurt (de Moraes et al., 2017).

The influence of enzymatic cross-linking of milk proteins on the probiotic culture survival and functional properties of goat milk yogurt is studied by Farnsworth and colleagues (2006). Yogurt was made by inoculating the milk with a commercial probiotic yogurt starter containing probiotic cultures (Lactobacillus acidophilus, Bifidobacterial, and Lactobacillus subsp.) after the milk had been pre-incubated with microbial transglutaminase [MTGase, 0–4 units (U)/g protein] for 1 hour at 50°C and then heat-inactivated for 5 minutes at 75°C. In comparison to the untreated control trial, pre-treatment of the milk with MTGase (2 and 4 U/g protein) increased P>0.05 the viscosity and decreased the syneresis of yogurt samples. Their results showed that increasing yogurt viscosity by enzyme treatment was more effective than increasing milk's total solids (TS) (Farnsworth et al., 2006b). The fundamental nutritional values of the control and enzyme-treated samples did not differ significantly. During an 8-week storage period at 4°C, the probiotic bacteria in goat milk yogurt remained very stable, with populations remaining above 106 CFU/g. The three probiotic cultures' population change rates did not differ significantly between the MTGase-treated and control groups. Enzymatic protein cross-linking has a beneficial effect on probiotic culture survival, according to microbiological research, which calls for more investigation. SEM research showed that the enzyme-treated samples' microstructure seemed denser than that of the control group, suggesting that milk might be pretreated with MTGase to improve the yogurt gel's microstructure. The results of this study suggest that goat milk yogurt's functional properties can be increased by the enzymatic cross-linking of milk proteins by MTGase. MTGase treatment may help create probiotic goat milk yogurt (Farnsworth et al., 2006b).

To assess the effects of pH and heat on the structure and function of milk proteins, Li et al. (2020) compared goat milk processed under various pH and temperature settings . According to their research, goat milk proteins' thermal stability was significantly impacted by pH, with pH 7.7 exhibiting the lowest degree of thermal stability. The greatest value of surface hydrophobicity for milk proteins at several pH levels was seen at 85°C, except for goat milk with a pH of 6.9 (XY Li et al., 2020). The quantity of regular secondary structure, zeta potential, and particle size were drastically decreased at 85°C, and the turbidity of milk proteins was lower in alkaline pH conditions than in acidic ones. It was shown that during heat processing, goat milk protein exhibited better foaming ability, foam stability, and water-holding capacity under acidic circumstances, whereas emulsion stability and oil-holding capacity were enhanced under alkaline settings. Additionally, it has been demonstrated that 85°C was the critical temperature for milk proteins once the milk's pH was adjusted (XY Li et al., 2020). Goat milk proteins are said to contain co-precipitates, functional and nutritional properties, and health benefits (Al-Kaisy et al., 2023), Co-precipitates of goat milk proteins shown better solubility and emulsifying properties in comparison to single protein isolates Goat milk proteins are rich in nutrients and include all the essential amino acids needed by the human body, along with a significant amount of minerals and vitamins. The food sector may benefit from the functional advantages of goat milk proteins in several applications, such as enhancing food items' texture, emulsification, and foaming capabilities. Additionally, studies have shown that the proteins in goat's milk have immunomodulatory and anti-inflammatory qualities. These proteins are thus being considered as a potential therapeutic strategy for a variety of illnesses (Al-Kaisy et al., 2023).

Based on a study by (Zhao et al., 2020b) on the effects of heat treatment on the microstructure and functional characteristics of whey protein derived from goat milk. This study investigated the effects of long-term treatments at different temperatures, as well as frequently used thermal processing techniques in the dairy industry, on the microstructure, denaturation, and

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functional characteristics of whey proteins (WP) derived from goat milk. Goat milk treated for 30 minutes at (>85°C) showed complete denaturation of WP, while temperatures greater than 85°C led to significant denaturation of WP. The secondary structure was least affected by low-temperature, long-term treatment, whereas regular structures gradually decreased with longer treatment times at ultra-high temperatures. Consistent with the denaturation results, the most severe morphological damage happened following treatment at 85°C for 30 minutes. This indicates that the functional qualities of WP from goat milk were significantly impacted by the degree of denaturation, particle size, surface hydrophobicity, and microstructure following heat treatment (Zhao et al., 2020b).

The Particle size, turbidity, zeta potential, and surface hydrophobicity of WP were all enhanced by heat treatment at 65°C for 30 minutes and 85°C for 15 seconds. The emulsifying activity index, water-holding capacity, oil-holding capacity, foaming capacity, and foam stability of WP were all improved by these changes. To provide the industry with a theoretical framework, the research attempted to reproduce the heat treatment conditions utilized in actual manufacturing (Zhao et al., 2020b).

Functional properties of goat milk

Goat milk has probiotic and prebiotic qualities. A prebiotic is a selectively fermentable substance that causes certain alterations in the makeup and activity of the gut microbiota, improving the host's health (Gibson et al., 2017). Goat milk is a natural source of oligosaccharides utilized in human nutrition and has a high content of prebiotics compared to the milk of other ruminants (Verruck et al., 2019a). Probiotics are living microorganisms that help the host's health when present in sufficient quantities (Hills et al., 2019). Taking probiotics can balance the microbiota in the gut, improve lactose metabolism, strengthen the immune system, and have anticarcinogenic benefits (Ranadheera et al., 2018a). Among dairy products not from cows, goat's milk is a main source of probiotics. Goat's milk has physical-chemical characteristics that help bacteria survive over time, including suitable pH, adequate buffering capacity, and high nutritional content (Ranadheera et al., 2018a). It has been used to isolate bacteria with potential probiotic properties from both raw goat milk and conventional goat milk yogurt (de et al., 2017).

The influence of enzymatic cross-linking of milk proteins on the probiotic culture survival and functional properties of goat milk yogurt is studied by Farnsworth and colleagues (2006). Yogurt was made by inoculating milk with a commercial probiotic yogurt starter containing cultures (*Lactobacillus acidophilus*, *Bifidobacterial*, and *Lactobacillus subsp*.) after the milk had been pre-incubated with microbial transglutaminase [MTGase, 0–4 units (U)/g protein] for 1 hour at 50°C and then heat-inactivated for 5 minutes at 75°C. Compared to the untreated control trial, pre-treatment of the milk with MTGase (2 and 4 U/g protein) increased viscosity and decreased the syneresis of yogurt samples ($P>0.05$). The results showed that increasing yogurt viscosity by enzyme treatment was more effective than increasing milk's total solids (TS) (Farnsworth et al., 2006a). The fundamental nutritional values of the control and enzyme-treated samples did not differ significantly. During an 8-week storage period at 4°C, the probiotic bacteria in goat milk yogurt remained stable, with populations remaining above 106 CFU/g. The population change rates of the three probiotic cultures did not differ significantly between the MTGase-treated and control groups. Enzymatic protein cross-linking has a beneficial effect on probiotic culture survival, according to microbiological research, which calls for more investigation. SEM research showed that the enzyme-treated samples' microstructure seemed denser than that of the control group, suggesting that milk might be pretreated with MTGase to improve the yogurt gel's microstructure. The study suggests that goat milk yogurt's functional properties can be increased by the enzymatic cross-linking of milk proteins by MTGase. MTGase treatment may help create probiotic goat milk yogurt (Farnsworth et al., 2006a).

To assess the effects of pH and heat on the structure and function of milk proteins, (Xing Li et al., 2020) compared goat milk processed under various pH and temperature settings. Their research found that goat milk proteins' thermal stability was significantly impacted by pH, with pH 7.7 exhibiting the lowest degree of thermal stability. The greatest value of surface hydrophobicity for

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milk proteins at several pH levels was seen at 85°C, except for goat milk with a pH of 6.9 (Xing Li et al., 2020). The quantity of regular secondary structure, zeta potential, and particle size were drastically decreased at 85°C, and the turbidity of milk proteins was lower in alkaline pH conditions than in acidic ones. It was found that during heat processing, goat milk protein exhibited better foaming ability, foam stability, and water-holding capacity under acidic circumstances, whereas emulsion stability and oil-holding capacity were enhanced under alkaline settings. Additionally, it was demonstrated that 85°C was the critical temperature for milk proteins once the pH was adjusted (Li et al., 2024). Goat milk proteins contain co-precipitates, functional and nutritional properties, and health benefits (Al-Kaisy et al., 2023). Co-precipitates of goat milk proteins showed better solubility and emulsifying properties compared to single protein isolates. Goat milk proteins are rich in nutrients and include all essential amino acids needed by the human body, along with significant minerals and vitamins. The food sector may benefit from the functional advantages of goat milk proteins in applications such as enhancing food items' texture, emulsification, and foaming capabilities. Studies have shown that goat milk proteins have immunomodulatory and anti-inflammatory qualities, making them a potential therapeutic strategy for various illnesses (Al-Kaisy et al., 2023).

Based on (Zhao et al., 2020a)'s study on heat treatment effects on whey protein derived from goat milk, long-term treatments at different temperatures and common thermal processing techniques in the dairy industry impact microstructure, denaturation, and functional characteristics of whey proteins (WP) derived from goat milk. Goat milk treated for 30 minutes at (>85°C) showed complete denaturation of WP, while temperatures greater than 85°C led to significant denaturation of WP. The secondary structure was least affected by low-temperature, long-term treatment, while regular structures gradually decreased with longer treatment times at ultra-high temperatures. The most severe morphological damage happened following treatment at 85°C for 30 minutes, indicating that WP's functional qualities were significantly impacted by the degree of denaturation, particle size, surface hydrophobicity, and microstructure following heat treatment (Zhao et al., 2020a). Particle size, turbidity, zeta potential, and surface hydrophobicity of WP were enhanced by heat treatment at 65°C for 30 minutes and 85°C for 15 seconds. These changes improved the emulsifying activity index, water-holding capacity, oil-holding capacity, foaming capacity, and foam stability of WP. To provide the industry with a theoretical framework, the research attempted to reproduce heat treatment conditions used in actual manufacturing (Zhao et al., 2020a).

Factors affecting the quality of goat milk.

Genetic traits: Within each species, there are great genetic differences due to breeds. Goat milk yield, quality, and composition likewise can have great differences, depending on the breed. It is reported that there were differences in milk yield and milk composition between goat breeds (Majid et al., 1994). The significant variation in the content of goat milk depends on the breed. For instance, milk fat can range from 2.3 percent to 6.9 percent and an average of 3.3 percent; milk protein can range from 2.2 percent to 5.1 percent and an average of 3.4 percent. Dairy goat breeds from Europe often have far greater milk production capacity than native types that have not been developed for it. Even when the normally larger solids content of the milk from native goats is taken into consideration, this difference still exists (Thompson et al., 2000). Because homozygosity's effects on permitting the expression of deleterious genes and inbreeding depression lead to inbreeding, it is typically unfavorable for the improvement of many qualities. This is typically the case for traits related to physical fitness, such as viability and procreative capacity (Barillet, 2007). Heterosis (hybrid vigor) is the outcome of crossbreeding for certain traits. When the average performance of crossbred offspring is better than the average of the two parents, it is obvious. The advantages could not last with consecutive crossings or grading-up if this impact is considerable (Thompson et al., 2000). The goat artificial insemination technique is already well-established, and future applications

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are likely to be more widespread. The utility is nevertheless restricted to locating exceptional bucks due to the typical modest size of dairy goat herds (Mukherjee, 1992).

Environmental and feeding system: Environmental (seasons) and nutritional factors (feeding systems) can cause variations in milk yield, quality, and composition. The chemical composition such as fats of milk can vary throughout seasons, especially under high temperatures (Yano et al., 2014). The feeding system is affected during the hot season(summer) because the composition of forages could change which in turn affects the dairy animals and their performance (Schwendel et al., 2015). Cold temperatures can decrease milk output (Mourad, 1992). Despite having heat-resistant traits, goats that are given milk are vulnerable to heat stress (Lu, 1989).

Stage of lactation: The stage of lactation is one of the major factors that affect milk yield and quality. The quality of milk, and its composition change during the lactation stages (Zahradeen et al., 2009). There are three main stages of lactation namely the early (less than 80 days DIM), mid (80-140 days DIM), and late (over 140 days DIM) lactation stages. Studies show that milk yield increases in early lactation, and decrease gradually as the lactation progresses to the end (Idowu & Adewumi, 2017). During early lactation, each component, protein, lactose, and solid non-fat showed the lowest values, and then significantly increased toward the late lactation stage (Idowu & Adewumi, 2017).

Diseases: Diseases such as mastitis, ketosis, and milk fever cause significant pathophysiological changes in the body of dairy animals, and in turn, negatively affect the yield, quality, and composition of milk. Some cases may bring up suspicions about milk safety for human consumption as well (Suh, 2022). Mastitis, as a common disease in dairy animals, can lead to the wastage of milk because of the presence of antibiotics in the milk during treatment. Mastitis has the potential to negatively impact the doe's milk production as well. The abundance of bacteria in the milk caused a reduction in milk production (Azooz et al., 2020). Mastitis directly affects the technical traits and wholesome condition of milk, indirectly altering natural qualities. The long-term effect of the disease can result in reduced milk production and changes in milk composition and quality, and it can also shorten the lifespan of the diseased animal (Halasa et al., 2007).

Parity: Age is directly connected to body size and parity (number of kidding) because it has an impact on milk supply. Body mass may grow until age six and then decline. Milk production also varies, reaching its peak between the ages of four and eight. According to research on Alpine goats, the second parity produced the highest yields (960 kg), while the seventh parity produced the lowest yields (634 kg) (Browning Jr et al., 1995). It is believed that the number of kids has an impact on the growth of the mammary during gestation. This is claimed to have an impact on milk supply, which is unaffected by age, body mass, or season. If the young are removed and fed by hand, milk production may also rise in response to suckling stimulation, although this does not affect dairy goats (Mourad, 1992). It is found that Saanen goats produce high milk yield in the first parity, they also discovered that fat and protein percentage rise until 17 months of age, then fall to the lowest value at 25 months of age, and then rise back at age 32 months to the levels which were fixed till 50 months of age (Zoa-Mboé et al., 1997). Processing also influences the quality and composition of the milk. During cheese preparation from milk and the effects of fermenting cheese, the various methods of processing, heating, and freezing can have profound influences on milk composition. Heating is applied during pasteurization, Ultra-high temperature processing, condensing, and powder production, which will alter the natural quality of milk proteins to varying degrees and affect flavors (O'Connor, 1994). Fig. 2 shows the schematic illustration of the factors influencing the quality of milk and temperature effect on goat production.

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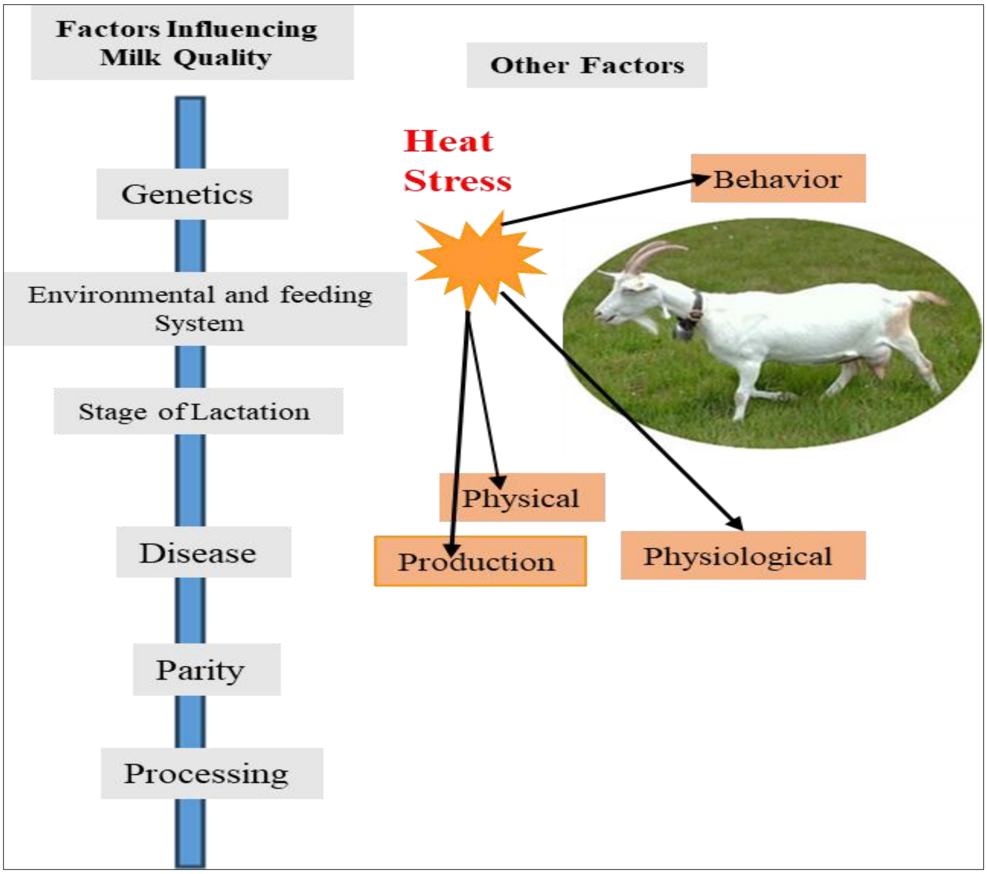

Fig. 2. Factor influencing the quality of milk and Temperature effect on goat production.

Goat nutritional needs and lactation stage

The nutritional content of milk is closely related to its composition and is impacted by breed, diet, seasonal fluctuations, and lactation stage the careful blending of several feedstuffs into a tasty ration that satisfies the unique nutrient requirements for lactation at various stages is necessary to achieve the best possible nutrition for dairy goats. Energy, protein, minerals, vitamins, and water are the main elements considered while formulating a diet for dairy goats. Variations in these nutrients are contingent upon circumstances such as lactation stage, gestation, growth, and season the performance, health, and financial results of a dairy goat operation are significantly influenced by the balance of these nutrients. According to Tovar-Luna et al. (2010), the effectiveness of employing dietary metabolizable energy for breastfeeding varies depending on the stage. Higher-concentration diets demonstrate greater effectiveness. It is difficult to supply milk demand when dry matter intake is falling behind, especially during early lactation. During this time, lead feeding is essential for determining the genetic potential of dairy dams. Peak dry matter coincides with mid-lactation, which corresponds with the nutritional needs for milk production (Kharrat & Bocquier, 2010).

Grain feeding during late lactation should correspond with milk output, with ad libitum high-quality hay or pasture as a supplement. It is important to maintain enough nourishment throughout the dry phase, as errors may harm the breastfeeding that follows. The effects of three diets on body weight, body condition, plasma metabolites, and milk production (yield, fat, and protein content) were tested: mountain natural rangelands in early lactation, agricultural pastures in mid-

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lactation, and indoor stall feeding in late lactation (Kouri et al., 2019). Findings revealed a drop in milk supply toward the conclusion of lactation in all feeding scenarios, suggesting that goats prefer to restock their bodies rather than continue producing milk to be prepared for the following cycle (Goetsch, 2016). Dairy goat nutrition is a primary factor influencing performance and production efficiency. Understanding this is crucial for diet formulation, predicting animal performance, and planning and controlling production systems at different lactation stages (Delgado-Pertíñez et al., 2013). When alternative feeds are introduced, their impact on animal performance should be assessed relative to the lactation stage. While Goetsch et al. (2001) observed that a high concentrate diet (65%) depressed milk yield in late lactation, this may not hold for overall energy efficiency and milk production throughout the entire lactation period in Alpine dairy goats (Min et al., 2005).

Comprehending the noteworthy influence of lactation phases in diverse investigations carries pragmatic consequences for enhancing feeding supervision and augmenting overall milk production over the lactation duration in dairy goats. Farmers can affect the performance of their dairy goats by applying targeted management techniques during various phases of lactation. Notably, implementing the right tactics following peak lactation may not only improve milk supply but also delay the post-peak drop and encourage breast involution close to drying off. Therefore, for goat dairy nutrition and decision support systems in herd management, understanding the physiological activity throughout different lactation phases is essential. Finding and elevating the flock's most productive animals requires an in-depth understanding of the udder activity unique to each lactation stage. Dairy producers may evaluate the effectiveness of their farming operations and maximize physical inputs for a larger gross profit margin by using the ability to estimate yearly milk output throughout different lactation phases.

Goat milk yield and lactation stages

The lactation curve plays a crucial role in determining milk production, with key factors such as peak yield and lactation persistency influencing overall productivity. Peak yield represents the maximum milk output during lactation, while persistency reflects the animal's ability to maintain a relatively constant milk yield post-peak (Mestawet et al., 2012a). An investigation on Damascus does in Sudan noted that different lactation stages impacted milk yield and composition, with chemical constituents decreasing as lactation progressed (S. Mahmoud & M. Azab, 2014). The decline in daily milk yield post-peak was attributed to lactation advancement, aligning with findings by Macdonald et al. (2008a) and supporting the work of Strzałkowska et al. (2009).

El-Tarabany et al. (2018a) studied three Egyptian goat breeds Baladi, Zaraibi, and Damascus and found high persistency in all breeds, with slightly higher yields in Zaraibi and Damascus during the initial lactation stages. Variations in milk production were observed between different lactations (Cismaș, Cziszter, et al., 2012). Kumar & Singh (2024) reported that fat, protein, lactose, ash, total solids, and solids nonfat percentages increased with lactation advancement across breeds. Milk quality in goats was affected by the stage of lactation, irrespective of rearing systems. Protein, lactose, and solid nonfat components exhibited the lowest values in early lactation, significantly increasing towards the end (Darwesh et al., 2013a). Aganga et al. (2002) studied the composition of Tshwana goat milk during lactation, noting fluctuations in mineral levels throughout the lactation period.

Muhammad et al. (2021a) observed a distinct pattern in the daily milk yields of Red Sokoto goats, noting a significant increase to a peak within two weeks, followed by a gradual decline until the end of lactation. The stage of lactation had a notable impact on milk constituents, with fat and protein contents showing a negative correlation, while lactose content exhibited a positive correlation with milk yield. This trend in milk yield may be attributed to the proliferation of myoepithelial cells in the mammary gland, particularly during the early stages of lactation. Garba et al. (2015) supported this observation, reporting a multiplication of mammary cells during early lactation that declines as

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lactation progresses. Vailati-Riboni, Elolimy, & Loor (2016) highlighted physiological and biochemical changes in the liver of highly productive dams during the early stage of lactation aiming to counteract the negative effects of energy imbalance.

The correlation between protein, lactose, fat, and dry matter yields with liver metabolite activity underscores the significance of liver functionality in lactating animals. Blood serum biochemical parameters are considered indicators of metabolic activity in lactating animals, providing insights into dairy dam nutrition and physiological status, particularly concerning age and stage of lactation (Bach, 2012). During lactation, mammary gland secretory cells utilize a substantial portion (80%) of circulating metabolites in the blood for milk synthesis. Determining biochemical parameters in blood serum offers information about metabolic activity in lactating animals. Milk yield, influenced by the number of mammary secretory cells and their metabolic activity, undergoes dynamic changes throughout the lactation period (Lawrence, 2022). Impaired lipogenesis and increased fatty acid release, stimulated by norepinephrine and epinephrine, lead to heightened lipase activity in the mammary gland, providing substrates for milk fat synthesis (Clegg et al., 2001).

Lactating goats exhibit an elevation in total serum protein levels as lactation progresses due to the catabolism of proteins for milk synthesis (Bionaz et al., 2012a). The composition of goat milk undergoes significant variations throughout lactation, with major changes typically occurring shortly after the onset of lactation. The initial secretion, known as colostrum, gradually transforms into mature milk. Efficient milking is crucial for goats during peak lactation, as there is a higher secretion rate during this stage (Dzidic et al., 2019a). According to Kuchtík et al. (2008a), the lactation stage has a significant impact on the composition of every component of milk. As lactation progresses, the levels of total solids, solids nonfat, fat, protein, and casein rise. Throughout the four lactation phases (colostrum, early, mid, and late), there are differences in the percentages of crude protein, fat, and lactose contents; however, the lactation stages do not affect total solids, pH, or ash contents (Hadef et al., 2018). The amounts of milk components in milk from both early and late lactation phases are greater (Mestawet et al., 2012). Rapid growth in milk production and large yields in the first lactation are linked to a later risk of udder illnesses in cattle. Once lactation peaks, cows with high milk output for a prolonged time but poor lactation persistency are more vulnerable to udder illness. There is no difference in the overall milk output at any stage between groups with and without udder illnesses, indicating that cows without udder problems have flatter lactation curves for a similar amount of lactation (Lee et al., 2020).

Goat crude protein and lactation stages

The lactational phase serves as a significant factor influencing the crude protein content of goat milk, as evidenced by studies such as Beyene & Seifu (2005) in Borana goat milk in Ethiopia and earlier findings by Idamokoro et al. (2017). A consistent trend in protein content was observed, showing a decline until mid-lactation, followed by a notable increase towards the end of lactation. This pattern aligns with other studies, such as Bautista et al. (2019), which reported a reduction in protein levels during mid-lactation and an increase in the late stage of lactation. Atasever & Stádník (2015) highlighted an inverse relationship between milk protein percentage and milk yield. Bjerre-Harpøth et al. (2012) noted a decrease in protein values during the early stage of lactation, followed by an increase until the end of lactation. This suggests that protein levels start at a moderate level, decrease during peak lactation, and gradually rise towards the end of lactation, consistent with the inverse relationship with milk production. Late lactation stages, as reported by previous researchers (Assan, 2014; Hinz et al., 2012; Reid et al., 2015), consistently exhibited the highest protein percentage, indicating a lower degree of proteolysis in late-lactation milk (Delger, 2021).

Goat fat content and lactation stages

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The structure of milk, particularly the fat and protein concentrations, plays a crucial role in determining its quality (Walker et al., 2004). Goat milk, in comparison to cow milk, is characterized by higher levels of long-chain fatty acids (Lopez et al., 2019; Nudda et al., 2021). Furthermore, goat milk contains a significantly greater proportion of short and medium-chain fatty acids than cow milk (Dalziel et al., 2020). The late stage of breastfeeding has the largest percentage of fat and total solids, with the early and mid stages following. The reason for this fluctuation is the inverse relationship between total solid content, fat, and milk production (Chamekh et al., 2020), a pattern observed by others such as Sharma et al. (2019). Hanuš et al., (2018) noted that fat content variations are linked to lactation stages, as well as factors like temperature, milk quantity, breed, and feed type. Pambu (2012) reported a decrease in milk fat in many goat breeds living in the same environment in South Africa from week one to week eight. According to Becker et al. (2020), the behavior of fat content tends to decrease as lactation advances, in contrast to Becker et al. (2020) findings, which showed a considerable rise in fat content in Borana goats with lactation stage. According to Bouattour et al. (2008) increased lipogenesis following peak lactation explains why milk fat output is usually higher during early lactation.

According to Gross et al. (2013) there is a decrease in fat content from the start of lactation until the middle of it, and then a steady increase until the end. This indicates that, like protein content, there is an inverse link between fat content and milk production. According to Zhang et al. (2020) the lactation stage has an impact on the fat content in goat milk. According to Toni et al. (2011) goat dairy products may taste different near the end of lactation when milk volume reduces due to increasing fat and protein content. There are breed-specific differences in goat milk lipolysis and lipoprotein lipase activity, with low levels during early and late lactation and underfeeding (Toni et al., 2011). Goat milk's conjugated linoleic acid concentration rises dramatically as lactation progresses (Zongo et al., 2021), while amounts can change depending on the makeup of the food (Park et al., 2007). Goat milk's short-chain fatty acid content peaks during the onset of lactation, influencing milk's and dairy products' sensory qualities and palatability (Palacios et al., 2009). The special properties of goat milk—especially its high concentrations of short- and medium-chain fatty acids, which have been shown to have medicinal benefits—remain unexplored and underappreciated despite these differences.

Lactose and lactation stages in goats

Lactose levels were initially higher during the early phase of lactation compared to the middle phase, as reported by Tao et al. (2009). The colostrum exhibited particularly high lactose content, which significantly decreased as lactation progressed. Previous studies also observed a continuous decrease in lactose content throughout lactation (Andjelić et al., 2022; Madsen et al., 2008). In contrast, Gulati et al. (2018) reported relatively consistent lactose levels throughout the entire lactation period, with no substantial changes. Darwesh et al. (2013b) found that lactose content reached its lowest point in early lactation, significantly increasing during mid and late lactation. This fluctuation in lactose content was among the smallest observed variations in milk components during different lactation phases (Heck et al., 2009). Lactose, functioning as an osmotic regulator and compensator for other milk components, demonstrated remarkable stability throughout lactation. It was highlighted that lactose is synthesized and secreted at a parallel rate to milk production, making it the most stable nutrient in milk (Mohammad et al., 2012). Furthermore, Udo et al. (2020) observed similar lactose compositions in West African dwarf goats at various lactation phases (early, mid, and late), highlighting the relative constancy of lactose in milk. A galactose molecule is joined to a glucose molecule to form lactose, a disaccharide produced in the udder.

Implications for dairy product quality and processing

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Somatic cell count (SCC) serves as a critical indicator of milk quality. It reflects mammary gland health and potential abnormalities in milk composition. Consequently, SCC plays a key role in national and international regulations governing milk quality, udder health, and mastitis prevention in dairy herds (S. J. More, 2009). The significance of milk quality extends beyond the dairy industry, influencing human health, milk processing, and overall, and on-farm profitability. Mastitis and its management have a considerable influence on farm profitability, resulting in a variety of economic repercussions such as treatment costs, productivity losses, culling, and milk quality changes (S. J. More, 2009). Elevated somatic cell counts (SCC) have been associated with lower milk production. High SCC in milk harms cheese production, including decreased curd hardness, lower milk output, increased fat and casein loss in whey, and a compromise in sensory quality (Coolbear et al., 2022). Furthermore, high SCC in milk has a detrimental impact on the quality of pasteurized liquid milk, resulting in a shorter shelf life. While high cell count milk itself does not pose direct risks to human health, there are indirect dangers associated with factors such as inadequate farm cleanliness, the presence of antibiotic residues, and the potential for pathogenic organisms and toxins in milk. These elements can contribute to health concerns for consumers (S. More, 2009).

Clinical and subclinical mastitis carry various economic implications, encompassing costs related to treatment, production losses, culling, and alterations in milk quality (Halasa et al., 2007). Collectively, these factors exert a significant impact on the overall economic viability of a farm. However, there exists a lack of uniformity among different studies regarding the reported costs of mastitis and the benefits derived from mastitis management. This lack of consistency is partly attributed to regional variations, such as differences in labor costs (Mansor, 2012). Additionally, Halasa et al. (2007) underscore the presence of crucial methodological differences among these studies, posing challenges for meaningful comparisons. To address this issue, the authors propose an economic framework to systematically evaluate the economic consequences of mastitis and its management. The decline in milk production is associated with elevated somatic cell counts (SCC). The extent of milk loss due to high SCC varies, ranging from 0.3 to 1.8 liters per cow per day, contingent on the lactation stage and the level of SCC (Green et al., 2006b; Hortet & Seegers, 1998). When accounting for the impact of dilution on SCC in high-yielding dairy cows, a slightly smaller decrease in production was observed (Green et al., 2006b). It seems that there is no reduction in milk output in cows with SCC up to approximately 100,000 cells/ml, hence, striving to reduce cow SCC below this threshold is unlikely to yield economic advantages (Green et al., 2006b). Milk quality has a substantial and negative impact on the milk processing business. Mastitis, defined by an influx of inflammatory cells resulting in 'high somatic cell count' milk, has been related to increased activity of heat-stable proteases and lipases. This increased exercise helps to break down casein and milk lipids (Moradi et al., 2021b). Mastitis-affected herds are at a higher risk of antibiotic residue violations due to increased antibiotic use (Moradi et al., 2021b; Ruegg & Tabone, 2000). The use of high somatic cell count milk in cheese production has several negative consequences, including decreased curd hardness, decreased cheese output, increased fat and casein loss in whey, and poor sensory quality (Murphy et al., 2016). High somatic cell count in milk is related to higher proteolysis during refrigerated storage even in the preparation of cottage cheese, which uses acid coagulation rather than rennet (Murphy et al., 2016). These effects have a deleterious influence on the production of milk protein concentrate (MPC), which contains both casein and whey proteins (Chandan & assurance, 2015). Mastitis also degrades the quality of pasteurized liquid milk and reduces its shelf life (Murphy et al., 2016).

Elevating the concentration of unsaturated fatty acids in the fat composition can enhance the health attributes of dairy products. However, this may not necessarily be deemed positive in terms of quality, as the double bonds in these unsaturated fats are susceptible to oxidation, potentially leading to the development of off-flavors during storage (Sajdakowska et al., 2018b; Scholz-Ahrens

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et al., 2020). Any increase in the concentration of unsaturated fatty acids must be accompanied by a rise in antioxidants, particularly if this 'healthier' milk is to be perceived as a quality product. Like fatty acids, there is evidence suggesting that dairy cows, especially those with high forage intakes, such as those from grazing, produce milk with elevated antioxidant levels. Nevertheless, there is no clear consensus regarding the situation with milk from organic or low-input production systems (Cabiddu et al., 2019b; Di Grigoli et al., 2019). These natural preservatives not only benefit consumers' health by preventing oxidation and cell damage after consumption but also offer protection against chronic diseases (Badr et al., 2021).

According to the research led by Murphy et al. (2016), raw milk characterized by elevated somatic cell and bacteria levels are linked to heightened enzyme activity, leading to potential product defects. The use of raw milk with somatic cell counts exceeding 100,000 cells/mL has been demonstrated to diminish cheese yields, and more substantial levels, typically surpassing 400,000 cells/mL, have been associated with textural and flavor defects in cheese and other dairy products. While most research suggests that a high total bacteria count (>1,000,000 cfu/mL) in raw milk is necessary to cause defects in most processed dairy items, obtaining high-quality milk from the farm allows for some flexibility in handling raw milk. This, in turn, enhances efficiency and reduces the risk of raw milk reaching bacterial levels of concern (Murphy et al., 2016).

It is imperative to monitor total bacterial numbers concerning raw milk quality, but the increasing importance lies in determining the levels of specific types of bacteria present. For instance, spores of certain spore-forming bacteria, even in exceptionally low levels (e.g., <1/mL) in raw milk, can survive pasteurization and proliferate in milk and cheese products to levels that result in defects. While testing for specific spore-forming groups is not currently a standard practice in quality incentive programs in the United States, it is employed in other countries, such as the Netherlands (Murphy et al., 2016). Based on the result (Schukken, 2007), bovine milk somatic cells primarily consist of lymphocytes, macrophages, and polymorphonuclear leucocytes, with a possible inclusion of a low percentage of epithelial cells. Elevated somatic cell count (SCC) levels in raw milk are indicative of mastitis, an inflammatory response of the mammary gland primarily caused by bacterial infection. While an SCC of approximately 70,000 cells/mL is considered average for milk from an uninfected, healthy udder quarter, counts ranging from 200,000 to 250,000 cells/mL are often utilized as benchmark values to identify infection. It's worth noting that mean SCC values can vary with factors such as age, days in milk, and production levels (Schukken, 2007).

In cases of infection, the SCC can surpass several million cells per milliliter in milk from an affected quarter, and as the percentage of infected quarters increases, so does the bulk tank somatic cell count (BTSCC). Although BTSCC has been employed to estimate the percentage of the herd affected, these values can vary based on the infecting agent, the stage of infection, and other influencing factors (Maréchal et al., 2011). Somatic cell count (SCC) is an essential indicator of milk quality, reflecting the health of mammary glands and potential abnormalities in milk composition. As such, SCC plays a crucial role in national and international regulations governing milk quality, udder health, and mastitis prevention in dairy herds (More, 2009). The importance of milk quality extends beyond the dairy industry, affecting human health, milk processing, and overall, on-farm profitability. Mastitis and its management significantly influence farm profitability, resulting in various economic repercussions such as treatment costs, productivity losses, culling, and changes in milk quality (S. J. More, 2009). Elevated SCCs have been linked to reduced milk production. High SCC in milk adversely affects cheese production, including decreased curd hardness, lower milk output, increased fat and casein loss in whey, and compromised sensory quality (Coolbear et al., 2022). Furthermore, high SCC in milk negatively impacts the quality of pasteurized liquid milk, shortening its shelf life. Although high cell count milk does not pose direct risks to human health, indirect dangers are associated with factors such as inadequate farm cleanliness, antibiotic residues, and the potential presence of pathogenic organisms and toxins in milk. These elements can contribute to consumer health concerns (S. J. More, 2009). Clinical and subclinical mastitis carry various

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economic implications, encompassing costs related to treatment, production losses, culling, and alterations in milk quality (Halasa et al., 2009). Collectively, these factors significantly impact the overall economic viability of a farm. However, there is a lack of uniformity among different studies regarding the reported costs of mastitis and the benefits derived from mastitis management. This inconsistency is partly due to regional variations, such as differences in labor costs (Mansor, 2012). Additionally, Halasa et al. (2009) highlight critical methodological differences among these studies, posing challenges for meaningful comparisons.

To address this issue, the authors propose an economic framework to systematically evaluate the economic consequences of mastitis and its management. The decline in milk production is associated with elevated SCC. The extent of milk loss due to high SCC varies, ranging from 0.3 to 1.8 liters per cow per day, depending on the lactation stage and the level of SCC (Gonçalves et al., 2018; Green et al., 2006a). When accounting for the impact of dilution on SCC in high-yielding dairy cows, a slightly smaller decrease in production was observed (Green et al., 2006). There appears to be no reduction in milk output in cows with SCC up to approximately 100,000 cells/ml, hence striving to reduce cow SCC below this threshold is unlikely to yield economic advantages (Green et al., 2006). Milk quality has a substantial and negative impact on the milk processing business. Mastitis, defined by an influx of inflammatory cells resulting in 'high somatic cell count' milk, has been associated with increased activity of heat-stable proteases and lipases. This increased activity helps break down casein and milk lipids (Moradi et al., 2021a). Mastitis-affected herds are at a higher risk of antibiotic residue violations due to increased antibiotic use (Moradi et al., 2021; Ruegg & Tabone, 2000). The use of high SCC milk in cheese production has several negative consequences, including decreased curd hardness, decreased cheese output, increased fat and casein loss in whey, and poor sensory quality (Murphy et al., 2016). High SCC in milk is related to greater proteolysis during refrigerated storage even in the preparation of cottage cheese, which uses acid coagulation rather than rennet (Murphy et al., 2016). These effects adversely affect the production of milk protein concentrate (MPC), which contains both casein and whey proteins (Chandan, 2015).

Mastitis also degrades the quality of pasteurized liquid milk and reduces its shelf life (Murphy et al., 2016). Increasing the concentration of unsaturated fatty acids in the fat composition can enhance the health attributes of dairy products. However, this may not necessarily be deemed positive in terms of quality, as the double bonds in these unsaturated fats are susceptible to oxidation, potentially leading to the development of off-flavors during storage (Sajdakowska et al., 2018a). Any increase in the concentration of unsaturated fatty acids must be accompanied by a rise in antioxidants, particularly if this 'healthier' milk is to be perceived as a quality product. Like fatty acids, there is evidence suggesting that dairy cows, especially those with high forage intakes, such as those from grazing, produce milk with elevated antioxidant levels. Nevertheless, there is no clear consensus regarding the situation with milk from organic or low-input production systems (Cabiddu et al., 2019a; Landau et al., 2023). These natural preservatives benefit consumers' health by preventing oxidation and cell damage after consumption and offer protection against chronic diseases (Badr et al., 2021). According to research led by Murphy et al. (2016), raw milk characterized by elevated somatic cell and bacteria levels is linked to heightened enzyme activity, leading to potential product defects. The use of raw milk with somatic cell counts exceeding 100,000 cells/mL has been demonstrated to diminish cheese yields, and more substantial levels, typically surpassing 400,000 cells/mL, have been associated with textural and flavor defects in cheese and other dairy products. While most research suggests that a high total bacteria count (>1,000,000 cfu/mL) in raw milk is necessary to cause defects in most processed dairy items, obtaining high-quality milk from the farm allows for some flexibility in handling raw milk. This, in turn, enhances efficiency and reduces the risk of raw milk reaching bacterial levels of concern (Murphy et al., 2016).

It is imperative to monitor total bacterial numbers concerning raw milk quality, but the increasing importance lies in determining the levels of specific types of bacteria present. For instance, spores of certain spore-forming bacteria, even in exceptionally low levels (e.g., <1/mL) in raw milk,

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can survive pasteurization and proliferate in milk and cheese products to levels that result in defects. While testing for specific spore-forming groups is not currently a standard practice in quality incentive programs in the United States, it is employed in other countries, such as the Netherlands (Murphy et al., 2016). Based on the results of (Schukken et al., 2009), bovine milk somatic cells primarily consist of lymphocytes, macrophages, and polymorphonuclear leucocytes, with a possible inclusion of a low percentage of epithelial cells. Elevated SCC levels in raw milk indicate mastitis, an inflammatory response of the mammary gland primarily caused by bacterial infection. While an SCC of approximately 70,000 cells/mL is considered average for milk from an uninfected, healthy udder quarter, counts ranging from 200,000 to 250,000 cells/mL are often utilized as benchmark values to identify infection. It is worth noting that mean SCC values can vary with factors such as age, days in milk, and production levels (Schukken et al., 2009). In cases of infection, the SCC can surpass several million cells per milliliter in milk from an affected quarter, and as the percentage of infected quarters increases, so does the bulk tank somatic cell count (BTSCC). Although BTSCC has been employed to estimate the percentage of the herd affected, these values can vary based on the infecting agent, the stage of infection, and other influencing factors (Maréchal et al., 2011).

CONCLUSION

Dairy goats hold significant promise for sustainable milk production, particularly in resource-limited regions and areas experiencing cow milk intolerance. Their historical role as a source of sustenance for disadvantaged communities highlights their exceptional efficiency in converting feed to valuable products like high-quality milk, meat, and fiber. This adaptability makes them well-suited for scenarios where other livestock might struggle. The rise of cow milk production issues and growing cow milk allergies further emphasize the potential of dairy goats. Moreover, as climate change necessitates environmentally conscious practices, the dairy goat production system offers a potentially more sustainable option. While existing research explores the purported health benefits of goat milk products, further scientific investigation, including clinical studies, is needed to substantiate these claims and elucidate their potential impact on consumer health. Future research directions should prioritize sustainable goat feeding strategies, enhanced milk and byproduct quality, and eco-friendly whey utilization methods to drive the advancement of the dairy goat production chain.

Effective lactation management strategies significantly influence dairy goat performance. Post-peak lactation techniques that optimize udder involution during drying-off periods can improve subsequent milk production and delay production decline. Understanding the physiological changes throughout the lactation stages is crucial for informed nutritional and management decisions, maximizing individual animal productivity. Furthermore, accurate annual milk production forecasts across lactation phases empower producers to evaluate farm efficiency and maximize profitability. However, inconsistencies in milk processing methods lead to variations in the physical-chemical and microbiological quality of milk and cheese. To address this, quality enhancement strategies or the use of heat-treated milk are essential for cheese production. Driven by consumer demand for cow milk alternatives, the dairy goat industry has witnessed significant growth, fostering innovation in product development. While seasonality in goat milk production poses challenges for large-scale operations, it also contributes to the distinct character of regional and traditional products. Moreover, breed selection plays a pivotal role in ensuring sustainability and high-quality production. Native breeds, with their superior adaptation to local climates and efficient use of resources, offer significant advantages.

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AUTHOR'S CONTRIBUTION STATEMENT

Sikiru Yesirat Adebukola, conceptualization, writing original Manuscript, main conceptual ideas, and proof outline, Noor Syaheera Binti Ibrahim: Literature review, were involved in planning and supervising the manuscript.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

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