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PHYSICOCHEMICAL AND MICROBIOLOGICAL ASPECTS OF GOAT MILK

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ABSTRACT - Goat milk is a high-quality food of fundamental importance for thousands of people involved in the socioeconomic development of this product, and dairy goat farms are well estasblished in the agricultural scenario, especially when analyzing small rural producers. The quality of goat milk is defined by its physicochemical and microbiological parameters. Adequate hygiene, handling, and management practices, from obtaining milk to commercialization, are of fundamental importance for guaranteeing food quality and safety for the consumer market. It is important to know the microbiological quality of milk, since it belongs to one of the most relevant food groups for the population. Brazilian legislation establishes minimum quality requirements for goat milk intended for human consumption in Normative Instruction 37/2000. The goals of this literature review were to present the issues related to the physicochemical composition, microbiological aspects, and nutritional properties of goat's milk as a reference measure and to highlight some characteristics. Despite the similarities with the milk of other animal species, goat milk is a unique product, and the study of this raw material is of great importance for industry as well as for the scientific community.
Keywords: Food security, production, dairy goats.

ASPECTOS FÍSICO-QUÍMICOS E MICROBIOLÓGICO DO LEITE DE CABRA

Resumo - O leite de cabra é um alimento de altíssima qualidade e de fundamental importância para milhares de pessoas que participam do desenvolvimento socioeconômico dessa cadeia produtiva, sendo a caprinocultura leiteira umas das atividades rurais que mais se desenvolve no cenário agropecuário, principalmente quando se analisa pequenos produtores rurais. A qualidade do leite de cabra é definida por seus parâmetros físico-químicos e microbiológicos. Práticas adequadas de higiene, manipulação e manejo, desde a obtenção do leite até sua comercialização, são de fundamental importância para garantir, qualidade e segurança alimentar para o mercado consumidor. É importante conhecer a qualidade microbiológica do leite, pois faz parte de um grupo dos alimentos mais relevantes para a população. A legislação brasileira estabelece requisitos mínimos de qualidade do leite de cabra destinado ao consumo humano na Instrução normativa 37/2000. O objetivo desta revisão de literatura foi apresentar as questões relacionadas à composição físico-química, aspectos microbiológicos bem como as propriedades nutricionais do leite de cabra como uma medida de referência e destacando algumas características. Apesar das similaridades com o leite de outras espécies animais, o leite de cabra é um produto único, e o estudo dessa matéria prima é de grande importância para indústria assim como para a comunidade cientifica.
Palavras-chave: segurança alimentar, produção, caprinocultura leiteira.

INTRODUCTION

Goat milk is considered a complete food because of its diverse composition of nutrients and essential elements for a healthy human body. Its quality is determined by the physicochemical and microbiological parameters that are part of the requirements of the market and processing industries. Appropriate hygiene practices, from obtaining milk through to its commercialization, are fundamental to ensuring the quality and food safety of the consumer market (MAGALHÃES, 2005). The survey of this information regarding the composition and physicochemical characteristics of goat milk is necessary for the production of a safe and high-quality product. Milk can show variations in its composition due to the influence of the breed, genotype of the animal, stage of lactation, feeding, and conditions of the environment (ALMEIDA et al., 2009). The value of the product can also be affected by the methodology adopted by the researcher.

In Brazil, Normative Instruction (IN) 37/2000 of the Ministry of Agriculture, Livestock and Supply (MAPA), regulates the production conditions, identity, and minimum quality requirements of goat milk for human consumption nationwide. The IN established that goat milk should have a fat content according to its classification: acidity from

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0.13% to 0.18%, minimum defatted dry extract of 8.2%, density at 15°C from 1.028 to 1.034 g mL^{-1}, cryoscopy from -0.530 to -0.564°C, total protein minimum of 2.8%, lactose minimum of 4.3%, and ash 0.7% (BRASIL, 2000).

The chemical properties of goat milk have nutraceutical characteristics that are superior to bovine milk, such as better digestibility, hypoallergenicity, and high protein content, which makes it attractive to those allergic to the most commercialized milk (cow's milk), along with providing quality nutrients for older adults and children (RIBEIRO; RIBEIRO, 2010).

In this context, studies that seek to characterize goat milk and its derivatives are of significant importance, because of the need to understand in detail this raw material to provide the scientific support essential for its development. Given the importance of dairy goat farming in Brazil, this study aimed to develop a literature review on the microbiological and physicochemical qualities of raw milk and the importance of goat milk consumption.

MATERIAL AND METHODS

This study involved a bibliographic survey and literature review based on scientific articles available in the Capes, Scielo, and Google Academic databases, addressing the aspects that permeate the production of goat milk and its physicochemical and microbiological characteristics.

Dairy goat raising

Goat farming is a source of protein in terms of both milk and meat, and along with the sale of the skin of these animals, has been linked to humans since the beginning of civilization (SILVA et al., 2012). Goats, along with sheep, are small ruminants that are economically exploited on all continents. However, only a few countries have great economic expression through goat farming, usually associated with the use of specialized breeds and advanced technologies (AQUINO et al., 2016).

Dairy goat farming is one of the most developed rural activities in the world. The Brazilian herd consists of approximately 8.2 million head, however 92.8% of the national herd is located in the northeast region of the country, since this region offers favorable climate conditions and a tradition of milk production in several mesoregions. Its activity results in a dynamic cash flow, which makes it more common among family farmers, who today produce 67% of the goat milk produced in Brazil (IBGE, 2017).

Important aspects of the legislation

According to Normative Instruction 37/2000, which provides for the technical regulation of production, identity, and quality of goat milk, the process is defined as "the product resulting from complete milking, uninterrupted, under hygienic conditions, from healthy, well fed, and rested goats" (BRASIL, 2000). According to the microbiological standards defined by this legislation, raw goat milk should have a standard plate count of 500,000 CFU mL^{-1} maximum (BRASIL, 2000). In addition, for routine evaluation of the raw material, the titratable acidity and relative density must be determined.

As for the production regulation, the breeding farm must be located in a rural area, or an urban or suburban area, as long as the municipal pasture codes are respected. In principle, it could be composed of an area for intensive or extensive breeding and milking facilities. It must have a room for milk processing unless the production is destined for another establishment for pasteurization or other industrial operations. The milking area may be built next to the barn, but must be exclusive to the purpose, and must be away from sources of strong odors and/or constructions that may cause damage to the hygienic production of milk. The milking platform must have a suspended floor made of wood or impermeable material, and the drinking water supply must have a maximum residual chlorine level (2 mg L^{-1}) to sanitize the equipment and installations (BRASIL, 2000).

Regarding the use of goat milk, it is only allowed when the females do not show clinical signs or positive results in diagnostic tests that indicate the presence of infectious-contagious diseases that can be transmitted to humans through the consumption of milk. Changes in the health condition of the animals must be considered because they can cause alterations in the quality of the milk, which justifies the condemnation of the product for human consumption. Females that present these conditions must be removed from the herd or production, according to the gravity of the case, either temporarily or permanently (BRASIL, 2000).

Quality of goat milk

The term quality refers to its hygienic quality, composition, volume, seasonality, technological level, and herd health. To respond to this need, quality criteria have been established in many countries, with hygienic, technological, and sensory parameters. Several dairy companies use these criteria as references for the value paid to producers, who have their production valued according to the quality of their product, from the nutritional, sensory, and microbiological perspective (RIBEIRO; RIBEIRO, 2010).

The negligence in the cleaning and disinfection of the teats and the milker hands, failure to wash the containers, the location where the milk is going to be transported or processed, and the environment where the animal is going to be milked, are factors that define the quality of goat milk. Consequently, the realizations of these premises contribute strongly to the high quality of the milk. Goat milk is an excellent matrix for the development of products with functional claims, such as low-fat, enriched or flavored drinks, cheeses, yogurts, ice cream, butters, and sweets (ARAUJO et al., 2019).

Nutraceutical characteristics of goat milk

Goat milk has been gaining prominence due to some peculiarities in its composition, such as smaller fat globules and absence of the substance agglutinin, factors that provide better digestibility to humans, as well as a lower

concentration of the casein portion (20%), which minimizes the likelihood of allergic reactions. Thus, goat milk is a food indicated by doctors for various sectors of the population, including children, older adults, and individuals allergic to cow's milk (MADUREIRA et al., 2017).

Regarding the fat concentration of goat's milk, it was observed that this product presents little difference when compared to cow's milk. However, the most significant difference was the higher proportion of short chain fatty acids (6–16 carbons) in goat milk fat. These short-and medium-chain fatty acids can aid in the treatment of a variety of clinical disorders and in the recovery of premature or undernourished children, because they are more selectively digested and absorbed and are used in the direct supply of energy, especially by children, as opposed to being deposited as fat in adipose tissue (BINDAL; WADHWA, 1993). In addition, butyric acid (C4:0) has attracted particular interest because of its beneficial effects on health, especially in regulating cell growth, associated with antineoplastic properties (PARODI, 2003).

Bacterial count in raw milk

The autochthonous microbiota of goat milk is of great industrial and economic interest. In addition to being useful for identifying the hygienic conditions of production and health of animals (by research on microorganism indicators of hygiene and pathogens), the autochthonous microbiota of this raw material can be exploited for the production of derivatives and food safety. Several studies have been published in various countries, aiming to characterize this microbiota with antimicrobial activity and technological potential, to be applied in the production of goat milk derivatives (MARTÍN-PLATERO et al., 2009; ASTERI et al., 2010).

Vittori et al. (2008) stated that it is important to know the microbiological quality of milk, as it is one of the most relevant foods for the population, and essential for humans. Milk with good hygienic quality should have a low bacterial count, absence of microorganisms pathogenic to humans, and absence of drug residues. Good hygiene practices during milking, storage temperature, and transportation of raw milk directly interfere with the total count of microorganisms (SANTOS; FONSECA, 2007).

Monte et al. (2017) evaluated the microbiological quality of goat milk produced by farmers in Cariri paraibano and observed the presence of microorganisms in the samples of raw milk analyzed. In another study, by Gottardi et al. (2008), total coliforms were identified in the goat milk samples, with counts ranging from 0 to 1.4 × 106 CFU mL^{-1}. The values found by Pádua et al. (2019) for the average count of mesophilic aerobic bacteria were 1–105 CFU mL^{-1}, with an average of 1.2 × 103 CFU mL^{-1}, which differed from that determined by Coelho et al. (2018) of 5.3 × 105 CFU mL^{-1}, which is higher than that allowable of 5.0 × 105 CFU mL^{-1} (BRASIL, 2000).

Physicochemical composition of goat milk

Acidity

Immediately after milking, milk presents a slight acidity, not because of the presence of lactic acid produced by the fermentation process but due to the presence of caseins, phosphates, albumin, carbon dioxide, and citrate (PEREIRA et al., 2001). Acidity is also dependent on the lactation phase, more specifically in relation to variations in casein content (SILVA, 1997).

The growth of lactic bacteria in milk transforms lactose into lactic acid, which is called acquired acidity. This type of acidity can be produced voluntarily depending on the conditions of the milk (AMIOT, 1991), and although lactic acid bacteria do not grow at temperatures below 5ºC, if the conditions are favorable, they are able to increase the lactose content and produce lactic acid (PRATA, 1998).

The high acidity values can be explained by the time that the milk has been without heat treatment and resting at room temperature, which can be from the milking period until the collection of samples (SILVA et al., 2011). High acidity may be related to the production of lactic acid by microorganisms, which may indicate hygiene failure. Regarding acidity, authors such as Coelho et al. (2018) and Santos et al. (2019) evaluated the physicochemical and microbiological quality of goat milk produced in the municipality of Petrolina-PE and observed a variation of 15.0 to 20.3°D, with an average of 17.13°D.

Barbosa et al. (2014) analyzed samples of raw milk from goats from different regions of the state of Paraíba and observed that the values obtained for acidity ranged from 15.563 to 21.824ºD. Pádua et al. (2019) retrieved milk samples from animals having an average value of 18.47°D and the pooled samples 18.5°D, in disagreement with the legislation (between 13ºD and 18ºD).

Density

The density of goat milk is relative and usually between 1.028 and 1.034 g mL^{-1} depending on whether it is individual milk or mixture milk, and the season, physiological state, and breed of the animal (BRASIL, 2000). According to Silva et al. (2008), values below the range established by the legislation IN 37/2000 (BRASIL, 2000) for this parameter may indicate the addition of water, and higher values could indicate fraud by the addition of other substances or milk skimming.

There are causes of normal variations in density that do not affect quality, such as milk composition in relation to fat content, protein value, and temperature at the time of determination. Among the abnormal causes of density variation, we can highlight the addition of water, which leads to a decrease in the density of the milk and, contrastingly, the skimming and addition of starch that increase the density, identifying economic fraud (AGNESE, 2002).

Almeida et al. (2000), when researching the quality of goat milk marketed in Juiz de Fora (MG), found very low values, ranging from 1027.15 to 1031.63 g L^{-1}, revealing that 10% of the samples produced in the city were in disagreement with the legislation. Coelho et al. (2018) observed that the density values of goat milk *in natura* ranged from 1028.11 to 1033.3 g L^{-1}, which is within the

values established by Brazilian legislation. Similar results were found by Souza et al. (2013), with 1030.0 and 1029.3 g L^{-1}.

Potential Hydrogen (pH)

Although the legislation (BRASIL, 2000) does not identify the ideal pH range for goat milk, Park et al. (2007) evaluated the physicochemical characteristics of goat and sheep milk and found a pH of goat milk that varied from 6.50 to 6.80. Among the physicochemical characteristics of milk, the most evident changes during mastitis occur in relation to pH and electrical conductivity. Electrical conductivity is increased in milk from animals with mastitis due to the high concentrations of Na and Cl ions, while pH retains an alkaline characteristic (SANTOS; FONSECA, 2007).

The pH and acidity values of milk are not proportional, although there is an inverse relationship, that is, as acidity increases, pH decreases. The difficulty in obtaining a good correlation is that when determining acidity, free hydrogen protons (ions) and accessible hydrogen protons (ionizable/dissociable) are quantified, whereas only free hydrogen protons (ions) are quantified when determining pH (SILVA; TORRES, 1995).

Fat

Regarding milk fat, its composition is formed almost entirely by triglycerides (98% of the total fat) that are synthesized in the epithelial cells of the mammary gland, and the fatty acids that compose these triglycerides can either come from lipids present in the blood or by synthesis in the epithelial cells (FONSECA; SANTOS, 2000).

Due to factors such as feeding, breed, season of the year, and lactation period, the concentration of fat in milk varies (SILVA, 1997). According to Brazil (2000), the fat content of goat species varies according to the classification of the milk. The amount of fat in the whole milk should not be altered, the amount in standardized milk is 3.0%, semi-skimmed milk has a fat content that varies from 0.6 to 2.9%, and skim milk, should contain fat levels of 0.5% or below.

Because milk fat synthesis is a dynamic process, dietary changes can alter the proportion of different fatty acids present. For example, when large amounts of concentrated feed are offered in the diet of dairy cows, there is a decrease in the proportion of acetic acid synthesis relative to propionic acid, which leads to a decrease in total fat synthesis by the mammary gland (PAULA et al., 2004). Dutra et al. (2014) and Ramos et al. (2020) obtained fat averages of 3.66 ± 0.19% in goat milk samples. In a study by Fonseca et al. (2006), mean values of 3.43 ± 0.18% and 3.40±0.15% were obtained.

Total Dry Extract (TDS) and Defatted Extract (ESD)

Dry matter or dry extract (DM) is defined as all components except water, and defatted dry extract (DDS) is defined as all milk components except water and fat. The dry matter percentage is an indispensable criterion for evaluating the integrity of milk. A minimum of 11.41% dry matter and 8.25% defatted matter is assumed for normal milk. Dry matter composition can be considered together with fat or without fat (BEHMER, 1980).

Studies show that the values found for TSS and ESD of goat milk are lower than those observed for cow milk, demonstrating that lower TSS and ESD values are characteristic of goats. According to data from the International Dairy Federation (IDF, 1987), the milk solids content is highly correlated with industrial yield for the production of dairy products, such as cheese and powdered milk, and should therefore be valued by the industry. Nascimento et al. (2018) analyzed the milk of Motoxó goats, and found TSS values of 18.80% and ESD values of 10.85%.

Protein

The chemical composition of goat milk consists of high biological value proteins and essential fatty acids, as well as high mineral and vitamin contents, which characterizes it as a food with good nutritional characteristics (SILVA et al., 2015). The main proteins can be divided into two groups, one consisting of caseins in the form of micelles (αs1-casein, αs2-casein, β-casein, and κ-casein), representing, on average, 80% of the proteins, and the other the soluble whey proteins, α-lactalbumin, β-lactoglobulin, serum albumins, and immunoglobulins. In addition, other less abundant soluble protein groups can also be found, such as lactoferrins, glycoproteins, and enzymes (PARK et al., 2007; RONCADA et al., 2012).

The proteins in goat milk play a role in their digestibility. Lower αs1-casein values found for some different breeds and genotypes, when compared to bovine milk, favor the formation of fine, smooth clots that are more easily and quickly attacked in the stomach by proteolytic enzymes. This facilitates the digestive process and reduces allergy-related problems for some individuals, since the time required for the allergy to disappear or show signs of improvement will depend on the severity of the initial reaction (BIDAT, 2010).

The proteins in goat milk occur in two distinct phases, a variable phase, composed of caseins in the form of micelles, measuring about 190 nm in diameter, interconnected by calcium phosphate and small amounts of magnesium, sodium, potassium, and citrate, and a soluble phase, composed of whey proteins. Casein precipitates at a pH of approximately 4.6 at room temperature, while serum proteins (β-lactoglobulin, α-lactalbumin, and blood serum albumin) under the same conditions remain soluble (PARK et al., 2007). The protein values of the samples analyzed by Coelho et al. (2018) ranged from 3.10 to 3.40%, thus above that established in the Brazilian legislation (above 2.8%) and higher than the results verified by Pinheiro et al. (2014) of 2.90 and 2.85%.

CONCLUSIONS

Goat milk production, despite the excellent nutritional characteristics and quality of raw material for derivative production, is a segment of the goat industry that still faces challenges in production, marketing, and commercialization in Brazil. The physicochemical and microbiological

analyses carried out by several authors show that the milks evaluated in the studies presented adequate conditions for the standards required by the Brazilian legislation, indicating the required quality for human consumption.

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