



Functionality of the components from goat's milk, recent advances for functional dairy products development and its implications on human health



Silvani Verruck^a, Adriana Dantas^b, Elane Schwinden Prudencio^{a,b,*}

^a Federal University of Santa Catarina, Department of Food Science and Technology, Rod. Admar Gonzaga, 1346, Itacorubi, 88034-001 Florianópolis, SC, Brazil

^b Federal University of Santa Catarina, Department of Chemistry and Food Engineering, Technology Center, Trindade, 88040-970 Florianópolis, SC, Brazil

ARTICLE INFO

Keywords:

Goat's milk
Goat products
Prebiotic
Probiotic
Functional food

ABSTRACT

The growing consumer interest in goat's milk and dairy products is related to nutritive values and positive health benefits attached to these products. Goat's milk is known for its lower allergenic potential and better digestibility, when compared to bovine milk, as well as the presence of health-promoting compounds. Therefore, goat milk can be used in the manufacture of a wide variety of products and can also be used as carrier for functional components, such as prebiotic substances or probiotic bacteria. Some *in vivo* studies have been carried out to explore its therapeutic potential and have shown excellent biological effects. However, probiotic/prebiotic research remains minimally explored regarding the functional aspects of goat dairy products. Thus, future studies using goat's milk products as probiotic/prebiotic matrix could be assessed in several models in a similar fashion to what is studied with bovine milk.

1. Introduction

The United Nations' Food and Agriculture Organization (FAO) statistics show that goat milk is the world's third most produced variety of milk, behind on cow and buffalo milk. In 2016 there were approximately 1 billion goats worldwide with a milk production of 15.262.116 tons. The largest producers of goat's milk are India, Bangladesh, and Pakistan in Asia; Sudan, South Sudan and Somalia in Africa; with France, followed by Spain, and Greece as the largest producers in Europe. Even though goat's milk production is still small in America, it has shown a substantial increase in recent years (FAOstat, 2018). Also, goat's milk production increased more than twofold in the last decades, with market trends suggesting that by 2030 will increase by another 53% (Pulina et al., 2018).

The growing consumer interest in goat's milk and its dairy products is related to the nutritional benefits offered by these products (Clark & García, 2017). For despite the similar composition to cow's milk regarding protein, fat and lactose concentration, there are differences between them that affect their digestibility and nutritional value. The differences between amino acid composition, the milk proteins' secondary structure, and the chemical properties of goat's milk help to reduce its allergenic potential when compared to cow's milk (Clark & García, 2017). In the United States and in other developed countries, this goat's milk is mostly consumed by people with intolerance to cow's

milk or suffers from digestive disorders (Pulina et al., 2018). It is worth noting that the fat globules present in goat's milk are smaller and its fatty acids have a smaller chain length when compared to cow's milk, which improve its digestive potential (Hodgkinson, Wallace, Boggs, Broadhurst, & Prosser, 2018). Goat's milk also possess health-promoting compounds, such as bioactive peptides; conjugated linoleic acids; and oligosaccharides (Abejón Mukdsi, Haro, González, & Medina, 2013; Assis et al., 2016; Kullisaar et al., 2003; Salva et al., 2011; Songisepp et al., 2005). These properties also aid the processing and commercialization of goat dairy products (Park, Juárez, Ramos, & Haenlein, 2007).

Goat's milk can be used to produce a wide variety of products, such as beverages, ultra-high temperature milk, fermented products (cheese, buttermilk, yogurt, and frozen yogurt), ice cream, butter, condensed/dried products, sweets, and candies (Aryana & Olson, 2017; Fazilah, Ariff, Khayat, Rios-Solis, & Halim, 2018; Kalyankar, Khedkar, & Patil, 2016). These products' high digestibility and low allergenicity also make them an excellent dietary staple for infants and the elderly (Haenlein, 2004). In this sense, goat's milk is also an excellent matrix for developing a large variety of innovative health-promoting products and functional foods (Silanikove, Leitner, Merin, & Prosser, 2010).

The demands of the consumer market have pushed the dairy industry to develop products aimed at providing functional components, such as the addition of prebiotic substances or probiotic bacteria (Bakr,

* Corresponding author at: Federal University of Santa Catarina, Department of Food Science and Technology, Rod. Admar Gonzaga, 1346, Itacorubi, 88034-001 Florianópolis, SC, Brazil.

E-mail address: elane.prudencio@ufsc.br (E.S. Prudencio).

<https://doi.org/10.1016/j.jff.2018.11.017>

Received 17 September 2018; Received in revised form 9 November 2018; Accepted 9 November 2018

Available online 16 November 2018

1756-4646/ © 2018 Elsevier Ltd. All rights reserved.

2015). Probiotics are defined as living microorganisms that, if consumed in adequate quantities, confer health benefits to the host (Hill et al., 2014). The International Scientific Association for Probiotics and Prebiotics has also reviewed the concept of prebiotic and the most recent definition considers it a substrate selectively used by host microorganisms that confer health benefits (Gibson et al., 2017). Functional foods containing prebiotics and probiotics have garnered the interest of the dairy industry both for economic reasons and due to scientific evidence related to their positive health benefits (Balthazar et al., 2017). The prebiotic and probiotic market is witnessing unprecedented growth (Silva et al., 2017). Thus, the combination of goat's milk and functional ingredients is one of the most promising research areas for the modern goat dairy industry.

Taking into consideration that use of prebiotics and probiotics is an emerging area to the development of goat's milk products, this review aims to show a complete picture of the current knowledge regarding the characteristics and advantages of goat's milk as a potential functional product and its benefits to human health. It also provides the necessary theoretical background and some details about the use of prebiotics and/or probiotics in goat milk products, facing the modern dairy products development worldwide.

2. Composition and functionality of goat milk compounds

The composition of goat's milk can vary according to genetic, physiological, environmental and handling factors (Mayer & Fiechter, 2012). Besides that, there is a wide variability in composition among individual animals of the same breed attributed to an extensive and complex genetic polymorphism of caseins found in goat's milk (Amigo & Fontecha, 2011). Although the total solids (TS), fat, protein, lactose, and ash contents of goat's milk is similar to that of cow's, important differences are found between the individual components of both kinds of milk (Park et al., 2007). In addition, the consumption of milk, including goat's, has been related to beneficial health effects due to the presence of health-promoting compounds (Abejón Mukdsi et al., 2013; Assis et al., 2016; Kullisaar et al., 2003; Salva et al., 2011; Salva, Villena, & Alvarez, 2010; Simos et al., 2011; Songisepp et al., 2005). Among these compounds are bioactive peptides and lipids, such as conjugated linoleic acids and other bioactive components like hormones, cytokines, oligosaccharides, nucleotides and minor components, which may have an important role on the development and maintenance of metabolic, immunological and physiological processes and thus contribute to the development of functional dairy products (Abejón Mukdsi et al., 2013; Assis et al., 2016; Kullisaar et al., 2003; Salva et al., 2011; Songisepp et al., 2005). A summary of the main agents of goat's milk beneficial effects are presented in Fig. 1.

The fat fraction is one of the most important components of goat's milk regarding its value, nutritional, physical and sensory characteristics (Amigo & Fontecha, 2011). The fat fraction is composed mainly of triacylglycerols (~98% of the total fat), with minor amounts of phospholipids, cholesterol, free fatty acids, and mono- and diacylglycerols (Taylor & MacGibbon, 2011). The fat in goat's milk is present in the form of globules, that do not aggregate naturally upon cooling as they lack agglutinin, which is responsible for the aggregation of fat globules in cow's milk (Amigo & Fontecha, 2011). Also, the lower size of the fat globules on the goat milk is one of the factors that increases its digestibility. As said before, the better digestibility of goat's milk compared to cow's milk is also related to differences in the fatty acids (FA) composition (Table 1). The capric, caprylic and caproic FA represent about 15–18% of all fatty acids present in goat's milk, while the same fatty acids represent only 5–9% in cow's (Clark & García, 2017). Differences in the polymerization of acetate produced by the rumen bacteria in the goat's stomach are responsible for this feature, and this particular composition is associated with the characteristic odor and flavor of goat's milk (Amigo & Fontecha, 2011). However, the most novel aspect reported to date regarding the composition of ruminant

milk fats concerns their content of conjugated linoleic acids (CLA), a group of naturally occurring 18-carbon fatty acids (Amigo & Fontecha, 2011). Some CLA isomers have been shown to offer health benefits and help disease prevention (Bauman, Tyburczy, O'Donnell, & Lock, 2011). Recent studies indicate that the consumption of milk and dairy products has a positive influence on human health and reduces the risks of cardiovascular disease, particularly noteworthy is the recognized activity of CLA in inhibition of cancer, atherosclerosis and an improvement of immune functions as a whole (Elwood, Pickering, Givens, & Gallacher, 2010).

Regarding the protein content, like in cow's milk, the caseins are classified as κ -, β -, α_{s1} -, α_{s2} -, and γ -caseins and the whey proteins as β -lactoglobulin, α -lactalbumin, serum albumin, and immunoglobulins (Table 2). The casein content in goat's milk represents 74% of total milk proteins, whey proteins amount nearly to 17% and the proportion of non-protein nitrogen compounds is 9% (Al-Saadi, Shaker, & Ustunol, 2014). The differences between the proteins among species are related to genetic polymorphisms and their frequencies in goat populations, mainly regarding α_{s1} -casein (Raynal-Ljutovac, Lagriffoul, Paccard, Guillet, & Chilliard, 2008). Therefore, the proportion of small-sized casein micelles is higher in goat's milk than that of cow's milk, which explains the better digestibility of goat's milk and its dairy products (Haenlein, 2004).

Regarding the soluble protein portion, differences also occur in the charged amino acids of α -lactalbumin between caprine and bovine milk, and two genetic variants have been reported having Lys or Ala as N-terminal residues (Amigo & Fontecha, 2011). The goat's β -lactoglobulin presented a lower net charge than the bovine one. During gastrointestinal digestion and/or during food processing, bioactive peptides can be formed from the precursor inactive protein. This protein fragments can be able to exert specific biological activities, such as antihypertensive, antimicrobial, opioid, antioxidant, immunomodulatory, or mineral-binding, as can be observed in Fig. 2 (Balthazar et al., 2017). The proteome analyses of goat's milk showed that some proteins present in it had not been found in cow's milk. These proteins are comprised of components that are precursor of peptides involved in potential hypotensive effects (i.e. angiotensinogen); are involved in the normal mammary gland development (i.e. dystroglycan); contribute to fetal immunological protection (factor H); or may be classified as defense factors (complement components C2 and C6) (Cunsolo et al., 2015).

Another important aspect concerning the goat's milk proteins is their lower allergenic capacity. Allergy to milk proteins, especially cow's milk, is an adverse reaction to milk ingestion, necessarily immunomodulated and classified as IgE mediated, non-IgE mediated or mixed (Fiocchi et al., 2010; Koletzko et al., 2012). Chatchatee et al. (2001), Ruiter et al. (2006), and Spuerger, Mueller, Walter, Schiltz, and Forster, (1996) reported that the main proteins responsible for allergy to cow's milk proteins are the α_{s1} -casein and β -lactoglobulin. As observed by Schulmeister et al. (2009), when 66 patients tested fragments of cow's α_{s1} -casein and synthetic peptides, the induction of degranulation of basophils was strong when the α_{s1} -casein was used intact. Elsayed, Hill, and Do (2004) demonstrated that N and C-terminal peptides of cow's α_{s1} -casein, 16–35 and 136–155, respectively, have higher binding affinity for IgE, while the epitopes 17–36, 39–48, 69–78, 93–102, 109–120, 123–132, 139–154, 159–174 and 173–194 were recognized as IgE ligands in children (Vila et al., 2001). Besides, due to its high resistance to intestinal hydrolysis and the fact that it is not found in human milk, β -lactoglobulin is also considered by many researchers just as responsible for cow's milk protein allergy (Bu, Luo, Chen, Liu, & Zhu, 2013; Verhoeckx et al., 2015). Chatchatee et al. (2001) observed that 13–76% of the patients presented a reaction with cow's β -lactoglobulin. Usually goat's milk also showed lower α_{s1} -casein and higher β -lactoglobulin content than cow's milk (Jandal, 1996). The genetic polymorphism that occurs in the proteins between the different species is what clarifies the potential use of goat's milk as a substitute to cow's

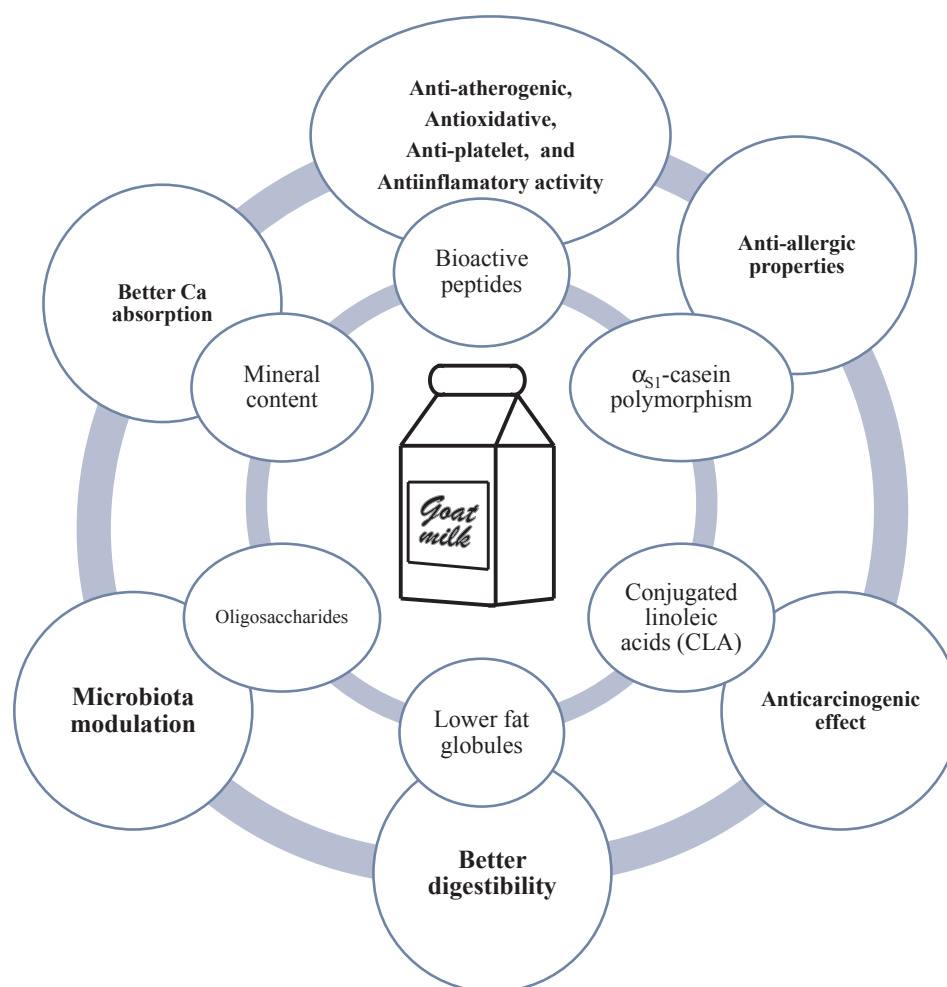


Fig. 1. Summary of the main agents of the beneficial effects of goat milk.

Table 1

Comparison on major fatty acids composition (%) of goat milk from those of cow milk.

Fatty acid	Goat milk	Cow milk
Butyric (C _{4:0})	2.18	3.70
Caproic (C _{6:0})	2.39	2.40
Caprylic (C _{8:0})	2.73	1.50
Capric (C _{10:0})	9.97	3.20
Lauric (C _{12:0})	4.99	3.60
Myristic (C _{14:0})	9.81	11.10
Myristoleic (C _{14:1})	0.18	0.90
Pentadecanoic (C _{15:0})	0.71	1.20
Palmitic (C _{16:0})	28.00	28.30
Palmitoleic (C _{16:1})	1.59	1.60
Stearic (C _{18:0})	8.88	11.80
Oleic (C _{18:1})	19.3	18.80
Linoleic (C _{18:2})	3.19	1.40
Linolenic (C _{18:3})	0.42	0.90
Linoleic conjugated (C _{18:2})	0.70	1.10
Minor acids	3.19	4.40

Source: Adapted from Amigo and Fontecha (2011) and Taylor and MacGibbon (2011).

milk when allergic disease is present (Ballabio et al., 2011). Haenlein (2004) and Park (1994) reported that 40–100% of allergic patients, sensitive to cow's milk proteins, are able to tolerate goat's milk proteins. In addition, the results of Lara-Villoslada, Olivares, Jiménez, Boza, and Xaus, (2004) showed that immunoglobulin G1 and histamine levels were significantly higher in cow's milk-sensitized mice than those

Table 2

Comparison of the protein composition of goat milk from those of cow milk.

Component	Cow milk	Goat milk
Total Caseins (g/100 mL)	2.40–2.80	2.33–4.63
α _{s1} -Casein	42.86–53.57	0 ^a –28.0
α _{s2} -Casein	10.71–14.28	10.0–25.0
β-Casein	32.14–39.28	0 ^a –64.0
κ-Casein	10.71–14.28	15.0–29.0
Total Whey Proteins (g/100 mL)	0.50–0.70	0.37–0.70
α-Lactalbumin	14.28–21.42	17.8–33.3
β-Lactoglobulin	28.57–57.14	39.2–72.1
Serum albumin	1.43–5.71	5.1–21.5
Immunoglobulin	8.57–14.28	4.6–21.4

Source: Adapted from Amigo and Fontecha (2011) and Swaisgood (2008).

^a Absence of β-casein or α_{s1}-casein in milk from animals carrying the respective null alleles. Individual caseins and whey proteins are expressed as a percentage of the total casein and total whey, respectively.

treated with goat's milk. Even if goat's milk is not an alternative for people with milk protein allergy, some studies demonstrated immune modulatory effects *in vitro* and in human tests (Jirillo et al., 2010).

Focusing on lactose, it is the major component of goat's milk; however, its content is about 0.2–0.5% less than that of cow's milk (Ceballos et al., 2009). Other types of carbohydrates present in goat's milk are oligosaccharides, glycopeptides, glycoproteins, and nucleotide sugars in small amounts (Amigo & Fontecha, 2011). A profile of the major oligosaccharide structures found in goat's milk is presented in

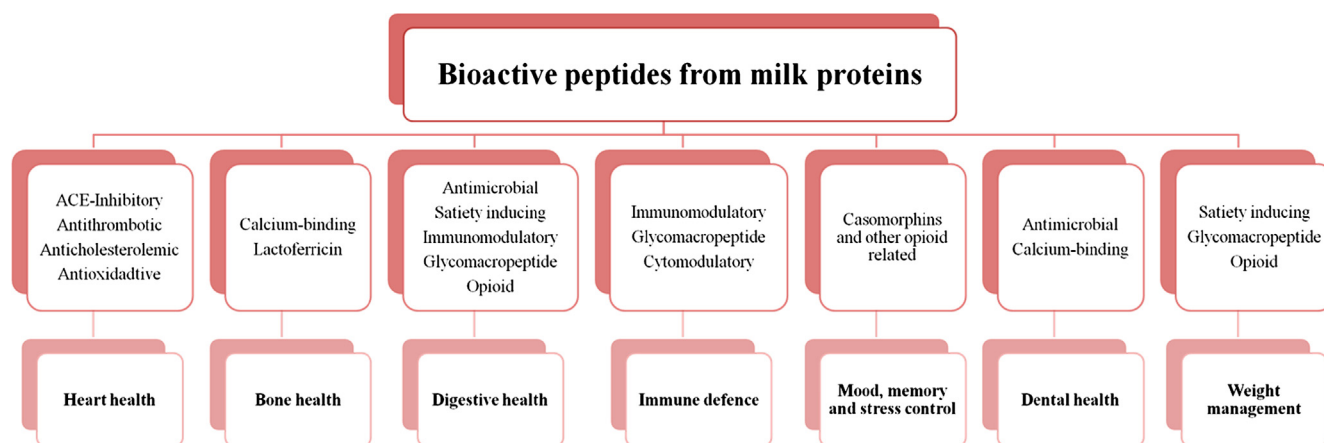


Fig. 2. Specific biological activities of bioactive peptides from milk. Adapted from Korhonen (2009).

Fig. 3. As reported by Park et al. (2007), goat's milk oligosaccharides have considerable antigenic properties and are valuable in promoting the growth of the intestinal flora in newborns. The concentration of goat's milk oligosaccharides is also higher than those of cow's and sheep's milk (Kiskini & Difilippo, 2013). These oligosaccharides are also structurally more similar to breast milk oligosaccharides when compared to other ruminant species (Giorgio, Di Trana, & Claps, 2018). The similarities found between breast and goat's milk oligosaccharides are related to the presence of neutral (galactosyl-lactose and lacto-N-hexaose) and sialylated (3-, 6-sialyl-lactose and disialyl-lactose) structures (Martinez-Ferez et al., 2006). Lara-Villoslada et al. (2006) reported that goat's milk oligosaccharides decrease intestinal inflammation in rats and contribute to the recovery of damaged colonic mucosa. Studies of health-promoting effects of goat's milk oligosaccharides are still scarce. Thus, this is an area that still requires studies in order to better understand these systems and how they interact together.

Ceballos et al. (2009) found higher levels of Ca, P, Mg, Fe and Cu in goat's milk when compared to cow's milk. The variability in mineral content of goat's milk is a result of genetics, diet, stage of lactation, and analytical procedures (Amigo & Fontecha, 2011). However, the better nutritional quality of goat's milk mineral composition is not just related to its composition, but also the manner which the human body makes use of it, both in digestive and metabolic processes (Ceballos et al.,

2009). Several studies reported that the increased bioavailability of magnesium, iron, calcium, copper and phosphorous from goat's milk in comparison to what is present in cow's (Alferez et al., 2006). Also, goat's milk contains a higher level of vitamin A than cow's milk since goats are able to convert all carotenes into vitamin A (Amigo & Fontecha, 2011).

3. Sensory and technological characteristics of goat milk

Dairy products made with goat's milk have stronger flavor and aromas than those found in dairy product made with other kinds of milk, an effect that may be explained by the higher amount of short-chain FA contents (Amigo & Fontecha, 2011). Among them are caprylic, capric and caproic FAs, where 4-methyloctanoic acid and 4-ethyloctanoic acid have been found to be the most responsible for the goat's milk flavor (Clark & Garcia, 2017). Furthermore, goat's milk also possesses branched-chain free fatty acids with less than 11 carbon atoms, which are virtually non-existent in cow's milk. These free fatty acids are responsible for the 'goaty' flavors characteristic of these dairy products (Amigo & Fontecha, 2011).

According to Vedran et al. (2010), during fermentation of goat's milk, its characteristic 'goaty' taste becomes less noticeable and the milk's nutritive value increases. Sensorial approaches have been used to

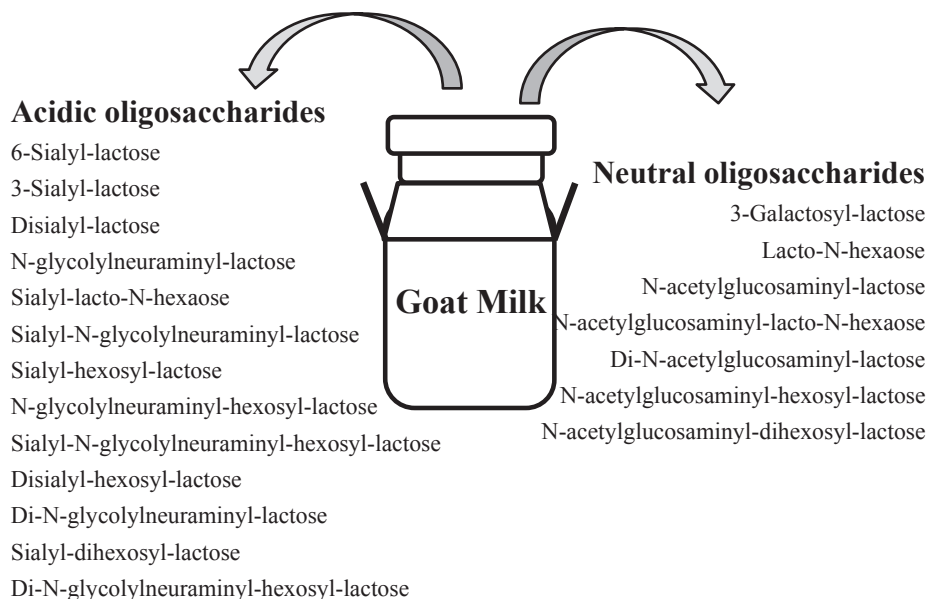


Fig. 3. Major oligosaccharide structures found in goat milk. Adapted from Martinez-Ferez et al. (2006).

decrease the 'goaty' flavor of some goat's milk products. This strategy was related with the repeated-exposure technique (Costa et al., 2014). A methodology that has been used as a promising tool to increase the overall taste of a food. However, Costa et al. (2014) found that after 6 days of rapid repeated-exposure, this method was not suitable to significantly increase the acceptance of goat's milk yogurt, suggesting that more time should be taken into account. On the other hand, there is a gap to be filled regarding innovative sensory methods for goat's milk products. However, methods that are already used for cow's milk products, such as temporal sensorial methods (Esmerino, Castura, et al., 2017), innovative methods of consumer perception (Esmerino, Tavares Filho, et al., 2017; Oliveira et al., 2017; Torres et al., 2017) as well as projective methods (Pinto et al., 2018; Soares et al., 2017) could be used with goat's milk as well, focusing on the evaluation of these products' characteristics and their relationship with the consumer. The use of these methods could help the goat's milk industry to devise strategies to develop the sector by making use of intrinsic (sensory attributes) and extrinsic (packaging, brand, price, and others) expectations of these products, while also taking into account socioeconomic and ethical aspects of goat's milk production (Pinto et al., 2018).

Color is another important sensory characteristic of goat's milk and its dairy products. Goat's milk shows a white color, since all of the β -carotene content is converted into retinol, and it is devoid of that pigment. In the CIELAB color coordinates, coordinates a^* and b^* depend on natural pigment concentration of goat's milk (Muelas et al., 2017). Sant'Anna, Gurak, Ferreira Marczak, and Tessaro, (2013) observed lower a^* values in goat's fresh Minas cheese after 14 days of storage, indicating a higher amount of greener tones than that of cheeses made with cow's milk, or a mixture of cow's and goat's milk. Meira et al. (2015) also observed similar values of a^* for goat's ricotta cheese. The b^* values (yellow component) were higher in cow's fresh Minas cheese when compared to cheeses made with goat's milk, or a mixture of both. This behavior was already expected, since cows transfer high carotenoid levels from their diet to milk and, consequently, dairy products made with cow's milk are yellower than those prepared with goat's milk. On the other hand, L^* value depends on the dispersion of casein micelles and fat globules that affect the diffusion of incident light (Nozière et al., 2006).

Amigo and Fontecha (2011) stated that the differences between cow's and goat's milk individual caseins affect the processing conditions, textural characteristics, and sensorial attributes of goats' milk products. Park et al. (2007) reported that the weak consistency of the curd formed during the coagulation of goat's milk is beneficial for human digestion but decreases its cheese yield. Also, this behavior is influenced by calcium and inorganic phosphorus content present in goat's milk, lower solvation, lower heat stability, and more readily loss of β -casein than cow's milk (Al-Saadi et al., 2014). The casein micelles in goat's milk are also smaller when compared to cow's milk; thus, being smaller and more friable, the caseins are attacked more rapidly by the stomach proteases (Clark & García, 2017). Therefore, the yield of goat cheese also depends on milk's composition, particularly fat and protein content (Guo, Park, Dixon, Gilmore, & Kindstedt, 2004). Goat's milk also exhibits higher non-protein nitrogen and lower casein nitrogen contents than cow's milk (Park et al., 2007), which may result in lower yields when manufacturing cheese made with goat's milk in comparison to cow's milk yield. However, the animal's breed influences the milk's properties, and consequently, those of dairy products. Goat's milk has been shown to exhibit a high percentage of α_{s1} -CN, which has been associated with higher cheese yields and firmer curds compared to milk from animals with lower α_{s1} -CN percentages (Sant'Ana et al., 2013). It is noteworthy that during cheese making, the milk's components remain as a colloidal dispersion (casein (CN) and calcium phosphate) and an emulsion (fat) that form a network, while the soluble constituents (whey proteins (WP), lactose and some minerals) are largely drained off with the whey. About 50% of the milk's solids are present in whey making it stand out as a useful source of nutrients

(Masotti, Cattaneo, Stuknytė, & De Noni, 2017). Thereby, whey is considered a by-product of cheese production and represents up to 90% of the total of volume of milk that enters the process (Muelas et al., 2017). The incorporation of whey proteins in cheese has been studied, and different approaches have been proposed (Giroux, Veillette, & Britten, 2018). The best-known method is the addition of heat-denatured WP to cheese milk. When added to cheese milk, WP aggregates are trapped within the pores of the casein network during the cheese-making process. In the work of Giroux et al. (2018), regardless of whey origin (cow, goat, or sheep), adding larger-diameter WP aggregates to cheese milk had no negative impact on rennet-induced coagulation, whereas smaller aggregates decreased curd firmness. WP aggregates of both diameter ranges reduced curd contraction capacity, which increased the curd mass fraction and moisture after the curd stretching step. In short, adding WP aggregates to milk increased cheese yield and moisture (Giroux et al., 2018).

Wang, Bao, Hendricks, and Guo, (2011) reported that the incorporation of polymerized whey proteins could decrease syneresis of goat's milk yogurt. According to them, whey protein-soluble aggregates were able to attach to the surface of casein micelles and this, in turn, favored the formation of bridges between the casein molecules, resulting in a less porous casein/heat-induced whey protein network. Moschopoulou et al. (2018) studied the syneresis of yogurts from skimmed and semi-skimmed sheep's milk, as well as semi-skimmed cow's and goat's milk. Their results showed that yogurt made with goat's milk displayed the highest water holding capacity (WHC). The authors suggest that the higher fat content of goat's milk also contributes to the increase of WHC since the fat globule membrane material improves the WHC of yogurt gels. However, despite this already known characteristic, researchers are continually seeking to further improve texture and viscosity parameters. Microstructural analysis showed that when polymerized whey protein was added to the yogurt a relatively more comprehensive network was formed, resulting in improved consistency and WHC. Even more, goat's milk is an excellent matrix for the development of a large variety of innovative health-promoting products and functional foods (Silanikove et al., 2010), such as via the addition of prebiotic substances or probiotic bacteria (Bakr, 2015).

4. Potentially functional food

The beneficial effect of certain types of functional foods and some of its components, have been studied in order to try and improve consumers health (Carrillo, Prado-Gascó, Fiszman, & Varela, 2013). Thus, foods with functional claims are those that, in addition to providing basic nutrition, promote health benefits (Carrillo et al., 2013). One of the priorities of worldwide research is to elucidate the properties of foods with functional claims (Annunziata & Vecchio, 2011). In this sense, goat's milk products with these properties could boost the sector through the development of innovative products and increase consumer demand (Aguilar-Toalá et al., 2018). According to Florowska, Krygier, Florowski, and Dłużewska, (2016) among foods with functional claims are those added with prebiotic substances or probiotic microorganisms, as can be observed in Fig. 4.

The dairy market represents a significant impact on functional foods, including products such as fermented milk, dairy beverages, cheeses and dairy desserts (Granato et al., 2010). The use of milk to produce functional foods is related to the milk's composition, which is a better matrix for probiotic bacteria than dietary supplements, such as lactic acid bacteria, and bifidobacteria (Champagne, Gomes da Cruz, & Daga, 2018). Probioactives are bioactive compounds, found in supplements or foods, that are directly linked to the presence or activity of probiotic bacteria. Some probioactives are also directly linked to the food matrix. As an example of probioactives, bioactive peptides specifically released by the hydrolysis of milk's casein only appear in fermented foods and not in supplements. This is another advantage to the use of a food matrix as probiotic carrier instead of supplements

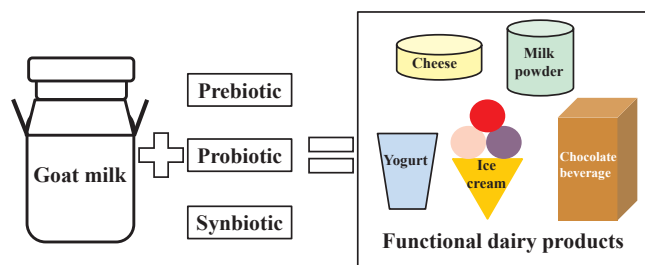


Fig. 4. Functional dairy products from goat milk and prebiotic, probiotic or symbiotic addition.

(Champagne et al., 2018). The probiotic bacteria find milk a rich source of carbohydrates that are quickly metabolized and converted into lactic acid other metabolites. Due to this, many products mainly use probiotics and prebiotics in order to receive “functional” status (Ranadheera, Naumovski, & Ajlouni, 2018). Hereinafter, the primary applications of prebiotics and probiotics in dairy products derived from goat’s milk will be discussed, as well as synbiotic products, which contain a combination of prebiotics and probiotics.

4.1. Prebiotic goat milk products

Although prebiotic foods have been studied and consumed for a long time, the use of the term prebiotic is recent, and its definition has been discussed and refined several times since it was first introduced in 1995 by Gibson and Roberfroid (1995). A designation that has been widely disseminated by the international scientific community reports that a prebiotic is defined as a selectively fermentable ingredient that results in specific changes in the composition and activity of the gastrointestinal microbiota conferring benefits to the host’s health (Gibson et al., 2010). The International Scientific Association for Probiotics and Prebiotics has reviewed this concept and the most recent definition of prebiotic considers it a substrate selectively used by host microorganisms that confer health benefits (Gibson et al., 2017). This new definition does not differ much from the previous one, however, the authors clarify that the prebiotics could also be administered directly to other sites of the body colonized by microorganisms, not necessarily being administered orally. This new definition also considers that the health effects of prebiotics are evolving, and although most known prebiotics are carbohydrates, other substances, such as polyphenols and polyunsaturated fatty acids, may be included in the current definition (Gibson et al., 2017).

Goat’s milk has a relatively high concentration of prebiotics in comparison to the milk of other ruminants (Oliveira, Wilbey, Grandison, Duarte, & Roseiro, 2012). Thus, goats’ milk is an attractive natural source of oligosaccharides to be used in human nutrition. A product enriched with these oligosaccharides was obtained following a two-stage tangential filtration process (Martinez-Ferez et al., 2006). Oliveira et al. (2012) reported that oligosaccharide-rich fractions from goat’s milk whey, collected after cheese making, had suitable functionality and promoted gut health. These authors stated that the concentrated oligosaccharides show application potential in the development of innovative goat’s milk functional products. However, other kinds of prebiotics can be added as well.

The addition of prebiotics may result in changes in the quality attributes of dairy products due to interactions between the functional ingredient and the components of the food matrix. The main prebiotics used in dairy products are inulin and oligofructose (Karimi, Azizi, Ghasemlou, & Vaziri, 2015). The variations in the degree of polymerization (DP) in industrial products are directly related to the technological properties of inulin and oligofructose when applied to different products (Mensink, Frijlink, Maarschalk, & Hinrichs, 2015). As it contains more free sugars, oligofructose has properties comparable to

sugar and glucose syrups. Raw oligofructose’s sweetness is only 30–35% of that of sucrose and presents a low caloric amount (1–2 kcal/g). Thus, they can be employed to replace carbohydrates in order to produce dairy products with reduced sugar content (Karimi et al., 2015). Paturi et al. (2018) studied the influence of the addition of prebiotics (inulin and oligofructose) to goat’s and cow’s powdered milk and their synergies with probiotics on the gut health of rats. These authors affirmed that the addition of inulin and oligofructose to goat’s powdered milk was able to induce positive changes in the gut microbiota composition and metabolism of rats, thus, promoting potential health benefits.

Inulin-type fructans are used as ingredients in the development of new products not only due to their nutritional properties but also for technological reasons. Inulin has a slightly sweet flavor (less than 10% of that of sucrose) depending on chain length, and exhibits moderate solubility in water (10% at room temperature) (Karimi et al., 2015). Inulin can also be used as a fat substitute in dairy products since it can promote a similar sensation in the tongue when ingested. Its higher molecular weight when compared to oligofructose makes it less soluble and able to form microcrystals when mixed with water or milk. These microcrystals are not perceived during consumption, but interact to form a smooth creamy texture (Mensink et al., 2015). In this sense, the effect of replacing fat with 2, 3 and 7% long-chain inulin (DP > 23) on the textural and microstructural properties of a fresh goat’s milk cheese was evaluated (Salvatore, Pes, Mazzarello, & Pirisi, 2014). These authors verified that cheese samples containing inulin had a more open structure compared to that of full-fat cheese due to the decreased fat distribution along the protein matrix. Thus, they concluded that samples containing inulin showed lower compressive force, stiffness, viscosity, and adhesiveness values.

Although new prebiotic substances are being evaluated and its applications are being discovered, there is a lack of application of prebiotic substances in goat’s milk products. Thus, this is an area that can be further investigated and has potential to increase the range of prebiotic products available to the market.

4.2. Probiotic goat milk products

The most up-to-date definition of probiotics defines them as living microorganisms that confer health benefits to the host when present in an adequate amount (Hill et al., 2014). The beneficial effects of probiotic consumption include balancing of intestinal microbiota, improvements to the digestive process, lactose metabolism, enhanced immune system response and anticarcinogenic properties (Ranadheera et al., 2018). In dairy products, the *Bifidobacterium* and *Lactobacillus* genus stands as the most used probiotic cultures (Champagne et al., 2018). The recommended minimum daily intake of probiotics is around 8–9 log of Colony-forming Units (CFU g⁻¹ or mL⁻¹), which can be achieved via the daily consumption of at least 100 g of a 6–7 log Colony-forming Units (CFU g⁻¹ or mL⁻¹ of the product) (Boylston, Vinderola, Ghoddusi, & Reinheimer, 2004). However, reports of non-viable (dead) microbial cells that are non-cultured, and possibly immunologically active, have also been related to show health benefits (Aguilar-Toalá et al., 2018). The term “paraprobiotics” was coined to “indicate the use of inactivated (non-viable) microbial cells or cell fractions to confer consumer health benefit” (Taverniti & Guglielmetti, 2011). Paraprobiotics have been previously reported in the literature as “inactivated probiotics” and “phantom probiotics” (Tsilingiri & Rescigno, 2013). These findings imply that bacterial viability is not an essential requirement in order to offer health benefits to the host, which presents a potential opportunity in the area of functional dairy products, and an emerging area to the development of goat’s milk products.

Goat’s milk is the major probiotic carrier among non-bovine dairy products. Yogurt, fermented milk, cheese and ice cream are the most commonly used goat’s dairy vehicles for probiotic cultures (Ranadheera et al., 2018). Many studies demonstrated satisfactory viability of probiotics in goat’s milk products throughout storage time (Table 3). Goat’s

Table 3
Probiotic strains used in the manufacturing of goat milk products.

Product	Probiotic strain	Conclusions	Reference
Fermented milk	<i>Lactobacillus plantarum</i> 69	The optimal fermentation conditions were the temperature of 35 °C, 0.07% of CaCl ₂ and 0.04% of Tween-80. The angiotensin-I-converting enzyme-inhibitory activity of the fermented product reach 91.62% after purification. Goat milk fermented by <i>Lactobacillus plantarum</i> 69 successfully survived in the gastrointestinal tract and maintained high angiotensin-I-converting enzyme-inhibitory activity.	(Chen, Zhang, Ji, Shu, & Chen, 2018)
Fermented milk	<i>Lactobacillus acidophilus</i> La-5 and <i>Bifidobacterium animalis</i> ssp. <i>lactis</i> Bb12	During storage, a slow and constant decrease was observed in lactobacilli counts; however, the final viability percentages of this organism did not differ significantly in the probiotic fermented milk tested. The cultured dairy foods made from cow, sheep, and goat milk had comparable <i>B. animalis</i> ssp. <i>lactis</i> BB-12 counts on day 0, exceeding by approximately 0.5 log ₁₀ cycle those in the camel milk-based product.	(Varga, Süle, & Nagy, 2014)
Fermented dairy beverage	<i>Bifidobacterium animalis</i> subsp. <i>lactis</i> and <i>Lactobacillus rhamnosus</i>	All beverages were good carriers for probiotic survival, maintaining viability above 7 log CFU/ml for 21 days. The addition of hydrolyzed galactomannan increased the dietary fiber content and the instrumental texture. The addition of hydrolyzed galactomannan improved the sensory characteristics of dairy beverages, especially texture, appearance and general acceptability.	(Buriti, Freitas, Egito, & Santos, 2014)
Fermented dairy beverage	<i>Lactobacillus acidophilus</i> LA-5, <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> BB-12 and <i>Propionibacterium jensenii</i> 702	All three probiotics were able to maintain high viability (> 10 ⁷ CFU/mL) during fermentation and subsequent storage (3 weeks). The acidity of all fermented milk samples increased during storage. However, there were no significant differences among preparations for organoleptic properties. Generally, lower sensory acceptability was recorded for the samples stored for 3 weeks than the respective fresh products. The probiotic bacteria remained viable (≥ 7 log CFU/mL) throughout the 28 days of refrigerated storage. The pH levels of the yogurts inoculated with <i>L. acidophilus</i> were lower than others yogurts (made without the probiotic). However, all yogurt samples underwent gradual decreases in pH until 7–14 days of storage. Apparent viscosity and firmness decreased in the yogurt elaborated with probiotic and cupuassu pulp. The cohesiveness remained constant in all yogurts at the end of the storage period (28 days).	(Ranadheera, Evans, Adams, & Baines, 2016)
Yogurt	<i>Lactobacillus acidophilus</i> La-5	The incorporation of honey positively affected the color characteristics, syneresis, viscosity, sensory acceptance and purchase intention of the yogurt. All yogurt formulations showed <i>L. acidophilus</i> La-05 counts above 6.0 log CFU/g during storage. The presence of honey increased the count of <i>L. acidophilus</i> La-05 and starter bacteria by approx. 1 log UFC/g at 21 days of storage.	(Costa et al., 2015)
Yogurt	<i>Lactobacillus acidophilus</i> La-05	The incorporation of honey positively affected the color characteristics, syneresis, viscosity, sensory acceptance and purchase intention of the yogurt. All yogurt formulations showed <i>L. acidophilus</i> La-05 counts above 6.0 log CFU/g during storage. The presence of honey increased the count of <i>L. acidophilus</i> La-05 and starter bacteria by approx. 1 log UFC/g at 21 days of storage.	(Machado et al., 2017)
Yogurt	<i>Lactobacillus acidophilus</i> LA-5, <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> BB-12 and <i>Propionibacterium jensenii</i> 702	<i>P. jensenii</i> 702 demonstrated the highest viability (10 ⁸ CFU/g) throughout the storage, while the viability of bifidobacteria (~ 10 ⁷ CFU/g) also remained above the minimum therapeutic level. The viability of <i>L. acidophilus</i> LA-5 fell below 10 ⁶ CFU/g. However, the addition of fruit juice favored its viability. The addition of fruit juice significantly increased syneresis and decreased the viscosity and water holding capacity of yogurts. The addition of fruit juice also increased its sensory acceptability.	(Ranadheera, Evans, Adams, & Baines, 2012)
Kefir	Starter culture under the joint trading code of 75106 (Abiasa Inc., Quebec, Canada)	Electrical conductivity increased 1.4-fold as a function of goat milk fermentation (7.242 Ω ⁻³ /cm). A significant dependence of electrical conductivity and pH was recorded during fermentation. The addition of mare milk to goat milk significantly slowed down the growth of LAB and yeasts during kefir production.	(Cais-Sokolinska, Wojtowski, Pikul, & Lasik-Kurdys, 2017)
Kefir	Starter culture under the joint trading code of 75106 (Abiasa Inc., Quebec, Canada)	The article explores the formation of volatile compounds during the production of kefir from goat and sheep milk with high polyunsaturated fatty acids (PUFA) as a result of changes in the animals' diet. Fermentation yielded less 2,3-butanedione. Neither the origin of milk (sheep or goat) nor the level of PUFA had any statistical effect on the amount of ethanal assayed during the fermentation of milk and within the	(Cais-Sokolinska et al., 2015)

(continued on next page)

Table 3 (continued)

Product	Probiotic strain	Conclusions	Reference
Kefir	<i>Lactococcus lactis</i> , <i>Lactococcus cremoris</i> , <i>Lactococcus</i> biovar. <i>diacetylactis</i> , <i>Leuconostoc mesenteroides</i> ssp. <i>cremoris</i> , <i>Lactobacillus plantarum</i> , <i>Lactobacillus casei</i> , and the yeast <i>Kluyveromyces marxianus</i> var. <i>fragilis</i>	finished product. The proportion of l(+) -lactic acid was higher in kefir produced using goat milk compared with sheep milk and did not depend on the content of PUFA in milk fat. An increase in PUFA content resulted in the loss of whey aroma in goat milk kefir. Strong inhibitory activity of the angiotensin-converting enzyme was found. The low molecular weight peptides released from the caseins during fermentation were the main responsible for this activity. Sixteen peptides with angiotensin-converting enzyme-inhibitory activity were identified, with emphasis on two of them (sequences PYVRYL and LVYPFTGPIP). Both the use of different cultures of probiotic lactic acid bacteria and storage time affected the volatile profile of the cheeses. The storage time had a more significant influence on the number of volatile compounds produced. A total of twenty-five aromatic compounds were identified in goat cheese. Esters and ketones may have a positive influence on the cheese, as its pleasant aroma can help minimize other undesirable odors.	(Quiros et al., 2005)
Coalho cheese	<i>Lactobacillus acidophilus</i> , <i>Lactobacillus paracasei</i> , and <i>Bifidobacterium</i> BB-12	The <i>L. acidophilus</i> count was about 7.5 log CFU/g in both kinds of cheese from control goat's milk and cheese from goat's milk enriched with conjugated linoleic acid (CLA) (obtained through a change in the diet of the goats). That is, the higher content of CLA in the cheese did not affect the viability of probiotics. Thus, the CLA-enriched probiotic caprine coalho cheese obtained is proposed as a vehicle for beneficial microorganisms and fatty acids.	(Bezerra et al., 2017)
Coalho cheese	<i>Lactobacillus acidophilus</i> LA-5	Incorporating the tested probiotics did not affect the yield or syneresis of the cheeses. The counts of <i>L. acidophilus</i> and <i>B. lactis</i> during the storage period were approximately 6 log CFU/g. No differences were observed in the fatty acid profiles between the samples. All samples were described as a soft cheese with homogeneous texture; however, cheeses containing <i>L. acidophilus</i> or <i>B. lactis</i> have been described as having a more acidic taste. At the end of exposure to simulated gastrointestinal conditions, the counts of probiotic strains tested were approximately 6 log CFU/g.	(Santos et al., 2012)
Ricotta cheese	<i>Lactobacillus acidophilus</i> La-5 and <i>Bifidobacterium animalis</i> ssp. <i>lactis</i> Bb12	The viability of <i>B. lactis</i> and <i>Lb. rhamnosus</i> cultures were unaffected throughout 35 days of storage at 4 °C, with a final count of > 7 log CFU/g. No significant difference was observed between probiotic treatments and control in pH and titratable acidity. <i>B. animalis</i> presented greater resistance to the artificial gastric and enteric juices than <i>Lb. rhamnosus</i> , with mean decreases in the initial populations of 0.2 and 4.0 log CFU/g within 35 days of storage, respectively.	(Meira et al., 2015)
Boursin-type cheese	<i>Bifidobacterium animalis</i> subsp. <i>lactis</i> and <i>Lactobacillus rhamnosus</i>	The addition of <i>B. animalis</i> decreased the pH, but it did not affect physicochemical properties. After 120 days of storage, the survival rate was 84.7%. Cell viability during gastrointestinal conditions resulted in a decrease of 3.82 cycles. Overall, goat's milk ice cream with <i>B. animalis</i> received good sensory scores, and satisfactory probiotic viability (6–7 log CFU/g) was maintained over the 120 days of frozen storage.	(Martins, Deliza, et al., 2018)
Ice cream	<i>Bifidobacterium animalis</i> subsp. <i>lactis</i> BI-07	The probiotic addition decreased the pH of the samples, and low overrun values (14.2–22.6%) were observed. Higher phenolic content for samples with the probiotic strain was observed, which suggests possible biotransformation that would lead to enhanced phytochemical level. Samples with probiotic showed counts of approximately 9 log CFU/g and probiotic survival rate of 97% during storage. Samples with probiotic bacteria received smaller taste scores, but similar results were obtained for appearance, aroma, and consistency among all samples.	(Silva et al., 2015)
Frozen yogurt	<i>Bifidobacterium animalis</i> subsp. <i>lactis</i> BI-07		(Bezerra et al., 2015)

milk could also facilitate long-term survival of probiotics due to its physical-chemical properties such as appropriate pH, good buffering capacity, and high nutrient content (Ranadheera et al., 2018). Also, raw goat's milk, as well as traditional goat's milk yogurt, has been widely used to isolate microorganisms with potential probiotic characteristics (Moraes et al., 2017; Sharma, Mahajan, Attri, & Goel, 2017; Yazdi, Davoodabadi, Zarin, Ebrahimi, & Dallal, 2017).

The development of fermented goat's milk containing probiotic bacteria has been recommended as a significant possibility to produce functional fermented dairy products (Balakrishnan & Agrawal, 2014; Chen, Wang, Li, Lu, & Li, 2015; Salva et al., 2011; Zhang et al., 2015). In Arab cultures, goat's milk is already extensively used as a carrier of probiotic bacteria in the form of stirred yogurt (Ismail, Hamad, & Elraghy, 2018). Zhang et al. (2015) compared the antioxidant and cholesterol-lowering activities of probiotic goat's and cow's milk fermented with bifidobacteria and lactobacilli and reported higher antioxidant activity and cholesterol-lowering effects in cultured goat's milk when compared to the results found for cow's milk. This may be explained due to structural differences and the presence of higher proteolytic activity in the primary structure of goat's milk when compared to cow's. In another study, Balakrishnan and Agrawal (2014) evaluated antioxidant activity and fatty acid profile of fermented cow's, goat's, and camel's milk prepared with *Pediococcus pentosaceus*. Antioxidant activity determined via DPPH assay showed a higher value for products made with goat's milk (93%) followed by camel's (86%) and lastly, cow's milk (79%). These authors suggest that probiotic bacteria can utilize the nutrients present in goat's and camel's milk more efficiently when compared to cow's milk. Quintana, Olalla-Herrera, Ruiz-Lopez, Moreno-Montoro, and Navarro-Alarcon, (2015) determined the Se, Cu, Cr, and Mn concentrations of different types of fermented goat's and cow's milk with bifidobacteria and/or lactobacilli. Selenium contents were significantly lower in fermented goat's milk products than in cow's milk fermented products. Data is still scarce regarding Se contents in fermented goat's milk, but similar Se contents were previously reported by Navarro-Alarcón et al. (2011). They have also found a significant linear correlation between Se and the proteins found in the studied products, related to its capacity to substitute sulfide-amino acids because of their similar ionic radius.

Kefir is another probiotic dairy product in which researchers are studying goat's milk as its basis. The starter culture is in the form of grains, and its microflora is complex and not constant, consisting of: bacteria – mesophilic and thermophilic LAB, acetic acid bacteria and possibly contaminants; yeasts; and mold (Tamime, Wszolek, Božanić, & Özer, 2011). The commercial kefir was developed in order to, among other factors, alleviate bulging and leaking of packages, caused by secondary yeast fermentation during the storage of traditional kefir. O'Brien, Aryana, Prinyawiwatkul, Ordonez, and Boenke, (2016) cited that a reduction of microbial diversity and beneficial exopolysaccharides may occur during commercial production, reducing some of its health benefits. Based on this, they did a study on the effects of frozen storage on the survival of probiotic microorganisms found in traditionally and commercially manufactured goat's milk kefir. The results obtained by these authors showed that the traditionally produced kefir exhibited significantly higher counts of bacteria and yeast at each sampling than commercial kefir. They also observed that frozen storage process could be a possibility to eliminate most packaging concerns associated with large-scale manufacture of traditionally produced kefir.

Set-type fermented cow's and goat's milk using polymerized whey protein (PWP) as the main thickening agent and Kefir Mild 01 as starter culture was developed by Wang, Wang, Wang, and Guo, (2017). The set-type fermented goat's milk with PWP and pectin had low syneresis, desirable viscosity, and appropriate hardness, which were comparable to fermented cow's milk. Sensory evaluation data showed that the set-type fermented goat's milk with PWP and pectin scored higher on both flavor and taste aspects than the sample without PWP. Scanning electron microscopy micrographs showed a compact and homogeneous

protein network of the set-type fermented goat's milk with PWP and pectin. These authors also report that the product fermented by Kefir Mild 01 starter culture had a similar taste with Kefir but no yeast or alcoholic compounds found, thus, the new product could be a promising food in the market.

The application of ultrafiltration processes to concentrate goat's milk constituents and increase the total solid fraction has been tested and studied. According to Gésan-Guizou (2012), this could be an important processing step in the manufacturing of cheese and dairy products. It has been reported by Bergillos-Meca et al. (2015) that the probiotic fermented milk prepared with goat's milk concentrated by ultrafiltration improved Ca, Mg, Zn and P bioavailability. In the same study, it was also verified that the improvement of Ca retention and uptake could be attributed to a positive effect exerted by the probiotic strain. Ultrafiltered goat's milk fermented with probiotic strain (*Lactobacillus plantarum* C4) also was utilized in other studies. Moreno-Montoro et al. (2017) investigated different whey fractions obtained from ultrafiltration process on fermented skimmed ultrafiltered goat's milk. Domagała, Wszolek, and Dudzińska, (2012) reported that probiotic yogurts prepared from goat's milk concentrated via ultrafiltration have better sensory properties and maintain a good texture.

Prasanna and Charalampopoulos (2018) microencapsulated *Bifidobacterium longum* subsp. *infantis* CCUG 52486 in a variety of matrices: sodium alginate (SA), sodium alginate-cow's milk (SACM), sodium alginate-goat's milk (SAGM) and sodium alginate-casein hydrolysate (SACH). The goat's milk-based matrix resulted in dense microcapsules which led to better performances in simulated gastrointestinal conditions than SA and SACH microcapsules. The bacterial cells encapsulated in SAGM showed the highest survival rate after 28 days of storage. The study showed that SAGM has a potential to be used as a new encapsulation material for encapsulating probiotic bacteria, resulting in milk and goat's milk-based products with higher probiotic cell concentrations during refrigerated storage (Prasanna & Charalampopoulos, 2018).

Bezerra et al. (2016) studied the proteolytic process in goat's coalho cheese supplemented with probiotic LAB (*Lactobacillus acidophilus* LA-5, *Lactobacillus paracasei* subsp. *paracasei* and *Bifidobacterium animalis* subsp. *lactis*, both isolated and in co-culture). It was verified that the addition of co-cultures influenced the cheese's proteolysis and resulted in a higher content of soluble protein and release of amino acids on the 1st day after processing. However, over 28 days of storage at 10 °C, the cheese supplemented with *Bifidobacterium lactis* in its isolated form showed the highest proteolytic activity, particularly in the hydrolysis of α_{s2} -casein and κ -casein fractions. Also, Setyawardani, Rahardjo, and Sulistyowati, (2017) studied proteolysis in function of the maturing process duration; their results indicated that 30 days of maturing at 5 °C was the primary contributing factor to chemical characteristics of probiotic goat cheese including proteolysis profile, pH, and FFA.

Goat's milk might also be utilized to produce ice cream with desirable textural properties, good sensory quality, and desirable melting characteristics (Açu, Kinik, & Yerlikaya, 2017). One important point is that the incorporation of probiotics into ice cream does not affect the product's overall quality (Silva, Bezerra, Santos, & Correia, 2015). On the other hand, the freezing and whipping processes involved in ice cream production may lead to severe cell damage and consequent loss of probiotic viability (Ranadheera, Evans, Adams, & Baines, 2013). However, satisfactory probiotic viability was obtained in goat's milk ice cream (Bezerra, Araujo, Santos, & Correia, 2015; Öztürk, Demirci, & Akın, 2018; Ranadheera et al., 2013; Silva et al., 2015).

4.3. Synbiotic goat milk products

The combination of one or more probiotics with one or more prebiotics gives rise to products called synbiotics. Thereby, prebiotics are complementary and synergistic to probiotics, presenting a multiplying factor on their isolated actions. This combination should allow the

survival of the probiotic bacteria in the food, and through the gastric environment, allowing for it to reach the intestines (Flesch, Poziomyck, & Damin, 2014). The potential synergy between probiotics and prebiotics was considered efficient due to improved survival and implantation of probiotics in the gastrointestinal system. One of the main benefits of synbiotics is to provide the highest persistence of probiotics in the gastrointestinal tract. The main reason for the advantage of synbiotics is that, in the absence of prebiotics, probiotics could not survive due to oxygen intolerance, low pH and unfavorable temperature (Shafi, Farooq, Akram, Hayat, & Murtaza, 2014). For example, inulin and fructooligosaccharides have a bifidogenic effect, that is, they stimulate the intestinal growth of bifidobacteria, which, by antagonistic effect, suppress the activity of other undesirable bacteria. The growth of bifidobacteria, stimulated by the fructooligosaccharides, leads to the reduction of pH due to the production of acids, affecting the reduction of the number of pathogenic or harmful bacteria, attenuating the formation of toxic metabolites (Gibson et al., 2017).

In the literature, there are several works involving the production of synbiotic goat dairy products. Examples of probiotic bacteria application, associated to prebiotics in dairy produced with goat's milk are described in Table 4. Cheeses, yogurt, dairy beverages, kefir, and ice cream are the most explored matrices. Dietary fibers with high water retention capacity can be used to prevent the syneresis and to modify the viscosity and texture of certain foods (Kinik et al., 2017). During the development of synbiotic creamy goat cheese, the addition of inulin showed interference in some texture parameters, such as the improvement of cheese's consistency. Thus, inulin and probiotics can be used together to produce creamy goat cheese without negatively affecting the product's overall quality, while also adding value due to its synbiotic potential (Barbosa et al., 2016). On the other hand, Lima et al. (2017) reported that the presence of *Lactococcus lactis* and a mix of inulin and oligofructose in goat cheese whey showed antibacterial activity against *Listeria monocytogenes*.

Due to the intrinsic characteristics of the formation of caseins gel from goat's milk, the consistency of yogurt made with this kind of milk is lower than cow's milk yogurts. To overcome this setback, Costa et al. (2015) proposed the addition of cupuassu pulp, *Lactobacillus acidophilus* LA-5 and inulin to improve the texture of goat's milk yogurt. *Lactobacillus acidophilus* LA-5 remained viable during storage, exceeding the minimum count required to confer probiotic physiological benefits. Their results showed that the consistency was higher in the yogurts with added inulin at the end of the storage period. Therefore, this approach could be an important technological strategy for the goat dairy

industry (Costa et al., 2015).

Goat cheese whey and the combination of inulin with oligofructose also can be used as functional ingredients in formulating a probiotic goat dairy chocolate beverage with improved viscosity and sensory characteristics (Silveira et al., 2015). Researchers are continually searching for new prebiotic compounds and their possible combinations with traditional probiotics, or other unknown microorganisms that may have their efficacy proven (Martharini & Indratningsih, 2017). Future research can optimize the content and profile of prebiotics present in plants by selecting varieties or changing agronomic and post-harvest practices to develop their innovative applications for the dairy industry and the promotion of health benefits.

5. *In vivo* studies with functional goat milk products

Some *in vivo* studies have been performed using goat's milk products with functional ingredients, mainly added with probiotic bacteria. A summary of *in vivo* studies, strains used and health claims evaluated are showed in Fig. 5. Most studies have been conducted with fermented milk with probiotic bacteria. Fermented milk products have been associated with health benefits, such as better lactose tolerance, intestinal microbiota balance, antimicrobial activity, immune system stimulation, antitumoural, anticholesterolaemic and antioxidative properties in human subjects (Kullisaar et al., 2003). Kullisaar et al. (2003) reported antioxidative and anti-atherogenic effects from fermented goat's milk using *Lactobacillus fermentus* ME-3 in healthy subjects. According to these authors, this occurs due to the prolonged resistance to oxidation of the lipoprotein fraction, lowered levels of peroxidized lipoproteins, oxidized LDL, 8-isoprostanes and glutathione redox ratio that enhanced the total antioxidative activity. In addition, the consumption of fermented goat's milk also altered both the prevalence and proportion of probiotic bacteria in the intestinal microbiota of human subjects involved in this study. *L. fermentus* ME-3 was also used in the manufacture of fermented goat's milk and compared with probiotic capsules in order to evaluate human body oxidative stress markers (Songisepp et al., 2005). After 3 weeks of consumption, a significant increase in the number of *Lactobacillus* spp. in the volunteer's feces was observed. The markers analyzed were total antioxidative activity, total antioxidative status and glutathione red/ox ratio (oxidized glutathione and reduced glutathione). The positive effect on the subjects' blood total antioxidative activity and total antioxidative status was observed in both formulations. However, the probiotic use in the goat's milk group showed better results when compared to the control and capsules

Table 4
Probiotic strains in association with prebiotic substances used in the manufacturing of goat milk products.

Product	Probiotic strain	Prebiotic	Reference
Cheese	<i>Enterococcus faecium</i> NRRL B-2354, <i>Bifidobacterium longum</i> NRRL B-41409, <i>Lactobacillus paracasei</i> subsp. <i>paracasei</i> NRRL B-4560	Inulin and oligofructose	(Kinik et al., 2017)
Creamy cheese	<i>Lactobacillus acidophilus</i> LA-05, <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> Bb-12	Inulin	(Barbosa et al., 2016)
Chevrotin cheese	<i>Bifidobacterium lactis</i>	Inulin	(Beltrao, Moura, Madruga, & Andrade, 2017)
Whey cheese	<i>Lactococcus lactis</i>	Inulin and oligofructose Mix	(Lima et al., 2017)
Cupuassu Yogurt	<i>Lactobacillus acidophilus</i> LA-5	Inulin	(Costa et al., 2015)
Yogurt (Rayeb milk)	<i>Lactobacillus acidophilus</i> and <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> Bb-12	Tamr and honey	(Ismail et al., 2018)
Chocolate goat dairy beverage	<i>Bifidobacterium lactis</i>	Inulin and oligofructose mix	(Silveira et al., 2015)
Kefir	Kefir grains and <i>Lactobacillus acidophilus</i> FNCC 0051	Plantain peel flour	(Martharini & Indratningsih, 2017)
Kefir	Kefir starter culture (DG)	Inulin	(Simsek, Sánchez-Rivera, El, Karakaya, & Recio, 2017)
Ice cream	<i>Lactobacillus paracasei</i> subsp. <i>paracasei</i> , <i>Bifidobacterium longum</i> and <i>Bifidobacterium bifidum</i>	Polydextrose	(Açu et al., 2017)
Goat's milk powder with microcapsules	<i>Bifidobacterium animalis</i> subsp. <i>lactis</i> Bb-12	Inulin and oligofructose	(Verruck et al., 2017; Verruck, de Liz, de Liz, Dias, de Mello Castanho Amboni, & Prudencio, 2018; Verruck, Santana, Müller, & Prudencio, 2018)

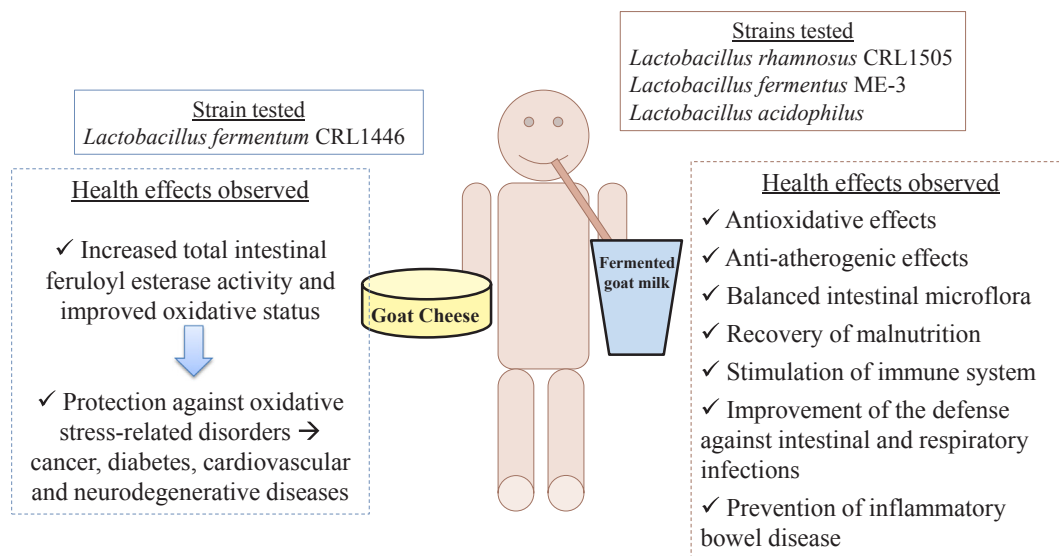


Fig. 5. Summary of *in vivo* studies with functional dairy products from goat milk, strains used and evaluated health claims.

group. Thus, assuring the functional efficacy of the probiotic *L. fermentum* ME-3 with antioxidative effects. The increase of the intestinal lactobacilli counts can provide putative defenses against enteric infections. Also, the reduction of oxidative stress indices in blood and urine could be tested as adjunct to conventional therapy in patients with atherosclerotic damages and high-grade oxidative stress. Salva et al. (2011) develops fermented goat's milk using *Lactobacillus rhamnosus* CRL1505. This strain was isolated from goat's milk in a previous study and specially designed for the recovery of immunocompromised hosts (Salva et al., 2010). Salva et al. (2011) studied the ability of this new product to accelerate the recovery of the nutritional status and immune response against respiratory and intestinal infections in immunocompromised malnourished rats. The stimulation of the mucosal immune system and an improvement of the defense against intestinal and respiratory infections were described by the authors.

Assis et al. (2016) tested the intestinal anti-inflammatory effect of goat's milk yogurt, added with *Lactobacillus acidophilus*, in rats with induced colitis. Their results demonstrate the prophylactic effect of goat's milk yogurt. The consumption of probiotic goat's milk yogurt caused a marked reduction in the macroscopic colonic damage, decreased the inflammation along the animal's colonic tissue, reduced the leukocyte infiltration, preserved the organ's tissue architecture, and decrease the pro-inflammatory mediators accompanied by an improvement of oxidative stress, with consequent preservation of the intestinal epithelium. Therefore, this goat dairy product may be a valuable alternative to traditional medications and a potential functional food for the prevention of inflammatory bowel disease.

Yogurts added with yacon flour were tested by Fabersani et al. (2018). *Smallanthus sonchifolius* (yacon) roots are considered a natural source of fructooligosaccharides (FOS). The authors investigated the effects of the addition of yacon flour on the quality parameters of goat's milk yogurt and the metabolic effects of its regular consumption on Wistar rats fed a high fat diet during 30 days. This study shows that even under a hypercaloric diet, the negative effects attributed to the high fat diet (body weight gain, increased body fat, altered glycemic response and lipid metabolism) were significantly improved by the administration of goat's milk yogurt with yacon. The results showed evidences indicating that goat's milk yogurt containing 7% of yacon flour is an excellent functional food that reduces the metabolic impacts of high fat diets. These authors concluded that this dairy product is an interesting technological option for small and medium-size dairy industries that wish to enter to the market of functional dairy foods.

Abejón Mukdsi et al. (2013) evaluated the effect of the intake of

goat's milk cheese produced with *Lactobacillus fermentum* CRL1446 on the intestinal activity of feruloyl esterase and oxidative status in Swiss albino mice. Feruloyl esterases are enzymes that degrade esters of ferulic acid, a phenolic compound (Abejón Mukdsi et al., 2013). This compound induces intrinsic antioxidant mechanisms such as superoxide dismutase, catalase and glutathione reductase activities that may provide protection against oxidative stress-related illness like cancer, diabetes, cardiovascular and neurodegenerative diseases (Srinivasan, Sudheer, & Menon, 2007). Thus, results of Abejón Mukdsi et al. (2013) show that dietary supplementation with probiotic goat's cheese for 7 days increased total activity of intestinal feruloyl esterase and improved the mice's oxidative resistance. This functional cheese would represent an innovative product providing protection against oxidative stress-related disorders.

Knowing that probiotics are able to modulate the intestinal microbiota and also aid in regulating inflammatory responses, Rodrigues et al. (2018) studied the effect of *Lactobacillus rhamnosus* EM1107, in isolated form as well as added to goat cheese, on rats afflicted with acetic acid-induced colitis. Treatment with *L. rhamnosus* EM1107 isolated or added to goat's milk cheese modulated the inflammatory response by suppressing the nuclear factor kappa B (NF- κ B p65) as well as aiding in the supra-regulation of suppressor of cytokine signaling-1 (SOCS-1). In addition, the probiotic was effective in protecting or restoring the cytoarchitecture of the colonic tissue. Intestinal immunohistochemical analysis revealed down-regulation of IL-17, NF- κ B p65, MMP-2, MMP-9, and iNOS expression, up-regulation of SOCS-1, ZO-1 and MUC-2, which are important intestinal mucosal barrier proteins. It is worth noting that *L. rhamnosus* EM1107 is a probiotic with potential benefits in the treatment of inflammatory bowel diseases. On the other hand, goat's milk whey also was used to improve inflammatory bowel disease response in rats (Araújo et al., 2016). Pre-treatment with goat's whey on colitic rats improved colonic inflammatory markers and significantly reduced the colonic oxidative stress by reducing malondialdehyde levels and increased total glutathione content, a potent antioxidant peptide. These results suggest that goat's milk whey exerted a preventive effect against the intestinal damage induced by acetic acid, showing a similar efficacy to that shown by sulfasalazine, making it a potential treatment for human inflammatory bowel disease.

The main probiotic research is focused on bovine dairy products due to the worldwide acceptability and the availability of this kind milk (Rodrigues et al., 2018). Nevertheless, goat's milk is also suitable as a carrier of probiotic bacteria and to produce functional goat dairy

products (Ranadheera et al., 2018). However, *in vivo* studies aiming to observe the effects of goat's milk products remain minimally explored (Rodrigues et al., 2018). As such, future studies using goat's milk or goat's milk products could be assessed in several studies, as for example, in the reduction of hypertension problems (Lollo et al., 2015), health improvements associated with physical exercise (Lollo et al., 2012, 2013), reduction of urolithiasis problems (Martins, Santos-Junior, et al., 2018) or even general health parameters (Moura et al., 2016). Finally, in the same way, as occurs with cow's milk, studies with humans should also be performed with goat's milk matrices in the future (Sperry et al., 2018).

6. Conclusions and perspectives

Goat's milk is an excellent source of nutrients, and its by-products are considered a delicacy in many countries. As such, these products have gained market size due to the greater knowledge of goat's milk chemical composition, which is rich in high biological value proteins, essential fatty acids, high mineral bioavailability and vitamin content. Nonetheless, the functional benefits of this food matrix remain unexplored by the dairy industry and consumers as a whole. More studies are also needed in order to investigate the effects of the addition of probiotic microorganisms and, especially, prebiotic components in goat dairy products. Although new functional substances are being evaluated and applications are made, there is a lack of prebiotic substances employed in goat's milk products. Thus, this is an area that can be further investigated and has potential to increase the range of prebiotic products available in the market. Also, it is known that probiotics viability is not an essential requirement to exert health benefits, which presents a potential opportunity in the area of functional dairy products, and an emerging area for goat's milk products development. Finally, some *in vivo* studies showed that beneficial effects have been attributed to the health of its consumers. However, further *in vivo* works are still needed in order to substantiate these allegations, mainly with other kinds of goat's milk products and other probiotic bacteria and/or prebiotic substances.

Conflict of interest

The authors declare that there is no conflict of interest.

Ethical statement

The material of our manuscript has not been published in whole or in part elsewhere. The manuscript is not currently being considered for publication in another journal. All authors have been personally and actively involved in substantive work leading to the manuscript and will hold themselves jointly and individually responsible for its content.

Acknowledgment

The authors are grateful to CNPq (National Council for Scientific and Technological Development, Brazil) by the financial support [CNPq, 405965/2016-8], and to CAPES (Coordination of Improvement of Higher Education Personnel, Brazil) by the scholarship.

References

- Abejón Mukdsi, M. C., Haro, C., González, S. N., & Medina, R. B. (2013). Functional goat milk cheese with feruloyl esterase activity. *Journal of Functional Foods*, 5(2), 801–809.
- Açu, M., Kinik, Ö., & Yerlikaya, O. (2017). Functional properties of probiotic ice cream produced from goat's milk. *Carpathian Journal of Food Science and Technology*, 9(4), 86–100.
- Aguilar-Toalá, J. E., García-Varela, R., García, H. S., Mata-Haro, V., González-Córdova, A. F., Vallejo-Cordoba, B., & Hernández-Mendoza, A. (2018). Postbiotics: An evolving term within the functional foods field. *Trends in Food Science and Technology*, 75(March), 105–114.
- Alfárez, M. J. M., López-Aliaga, I., Nestares, T., Díaz-Castro, J., Barrionuevo, M., Ros, P. B., & Campos, M. S. (2006). Dietary goat milk improves iron bioavailability in rats with induced ferropenic anaemia in comparison with cow milk. *International Dairy Journal*, 16(7), 813–821.
- Al-Saadi, J. S., Shaker, K. A., & Ustunol, Z. (2014). Effect of heat and transglutaminase on solubility of goat milk protein-based films. *International Journal of Dairy Technology*, 67(3), 420–426.
- Amigo, L., & Fontecha, J. (2011). Goat milk. In J. W. Fuquay, P. F. Fox, & P. L. H. Mcsweeney (Eds.). *Encyclopedia of dairy sciences* (2nd ed.). London, UK: Elsevier Ltd 3:484-3:493.
- Annunziata, A., & Vecchio, R. (2011). Functional foods development in the European market: A consumer perspective. *Journal of Functional Foods*, 3(3), 223–228.
- Araújo, D. F., de, S., Guerra, G. C. B., Júnior, R. F., de, A., Antunes de Araújo, A., Antonino de Assis, P. O., Nunes de Medeiros, A., Queiroga, R., de, C. R., & do, E. (2016). Goat whey ameliorates intestinal inflammation on acetic acid-induced colitis in rats. *Journal of Dairy Science*, 1–12.
- Aryana, K. J., & Olson, D. W. (2017). A 100-Year Review: Yogurt and other cultured dairy products. *Journal of Dairy Science*, 100(12), 9987–10013.
- Assis, P. O. A. de, Guerra, G. C. B., Araújo, D. F. de S., Araújo Júnior, R. F. de, Machado, T. A. D. G., Araújo, A. A. de, ... Queiroga, R. de C. R. do E. (2016). Intestinal anti-inflammatory activity of goat milk and goat yoghurt in the acetic acid model of rat colitis. *International Dairy Journal*, 56, 45–54.
- Bakr, S. A. (2015). The potential applications of probiotics on dairy and non-dairy foods focusing on viability during storage. *Biocatalysis and Agricultural Biotechnology*, 4, 423–431.
- Balakrishnan, G., & Agrawal, R. (2014). Antioxidant activity and fatty acid profile of fermented milk prepared by *Pediococcus pentosaceus*. *Journal of Food Science and Technology-Mysore*, 51(12), 4138–4142.
- Ballabio, C., Chessa, S., Rignanese, D., Gigliotti, C., Pagnacco, G., Terracciano, L., ... Caroli, M. (2011). Goat milk allergenicity as a function of α -casein genetic polymorphism. *Journal of Dairy Science*, 94(2), 998–1004.
- Balthazar, C. F., Pimentel, T. C., Ferrao, L. L., Almada, C. N., Santillo, A., Albenzio, M., ... Cruz, A. G. (2017). Sheep milk: Physicochemical characteristics and relevance for functional food development. *Comprehensive Reviews in Food Science and Food Safety*, 16(2), 247–262.
- Barbosa, I. C., Oliveira, M. E. G., Madruga, M. S., Gullon, B., Pacheco, M. T. B., Gomes, A. M. P., ... Queiroga, R. C. R. E. (2016). Influence of the addition of *Lactobacillus acidophilus* La-05, *Bifidobacterium animalis* subsp. *lactis* Bb-12 and inulin on the technological, physicochemical, microbiological and sensory features of creamy goat cheese. *Food & Function*, 7(10), 4356–4371.
- Bauman, D. E., Tyburczy, C., O'Donnell, A. M., & Lock, A. L. (2011). Milk lipids: Conjugated linoleic acid. In J. W. Fuquay, P. F. Fox, & P. L. H. Mcsweeney (Eds.). *Encyclopedia of dairy sciences* (pp. 3:660–3:664). (2nd ed.). London, UK: Elsevier Ltd.
- Beltrao, F. A. S., Moura, C. V. R., Madruga, M. S., & Andrade, A. E. B. (2017). Avaliação do perfil de ácidos graxos de queijo tipo Chevrotin simbiótico. *Revista do Instituto de Laticínios Cândido Tostes*, 72(1), 11.
- Bergillos-Meca, T., Cabrera-Vique, C., Artacho, R., Moreno-Montoro, M., Navarro-Alarcon, M., Olalla, M., ... Ruiz-Lopez, M. D. (2015). Does *Lactobacillus plantarum* or ultrafiltration process improve Ca, Mg, Zn and P bioavailability from fermented goats' milk? *Food Chemistry*, 187, 314–321.
- Bezerra, M., Araujo, A., Santos, K., & Correia, R. (2015). Caprine frozen yoghurt produced with fresh and spray dried jambolan fruit pulp (*Eugenia jambolana* Lam) and *Bifidobacterium animalis* subsp. *lactis* BI-07. *LWT – Food Science and Technology*, 62(2), 1099–1104.
- Bezerra, T. K. A., Arcanjo, N. M. O., Araújo, A. R. R., Queiroz, A. L. M., Oliveira, M. E. G., Gomes, A. M. P., & Madruga, M. S. (2017). Volatile profile in goat coalho cheese supplemented with probiotic lactic acid bacteria. *LWT – Food Science and Technology*, 76, 209–215.
- Bezerra, T. K. A., de Araujo, A. R. R., do Nascimento, E. S., Paz, J. E. D., Gadelha, C. A., Gadelha, T. S., & Madruga, M. S. (2016). Proteolysis in goat “coalho” cheese supplemented with probiotic lactic acid bacteria. *Food Chemistry*, 196, 359–366.
- Boylston, T. D., Vinderola, C. G., Ghoddusi, H. B., & Reinheimer, J. A. (2004). Incorporation of bifidobacteria into cheeses: Challenges and rewards. *International Dairy Journal*, 14(5), 375–387.
- Bu, G., Luo, Y., Chen, F., Liu, K., & Zhu, T. (2013). Milk processing as a tool to reduce cow's milk allergenicity: A mini-review. *Dairy Science and Technology*, 93(3), 211–223.
- Buriti, F. C. A., Freitas, S. C., Egitto, A. S., & Santos, K. M. O. (2014). Effects of tropical fruit pulps and partially hydrolysed galactomannan from *Caesalpinia pulcherrima* seeds on the dietary fibre content, probiotic viability, texture and sensory features of goat dairy beverages. *LWT – Food Science and Technology*, 59(1), 196–203.
- Cais-Sokolinska, D., Wojtowski, J., Pikul, J., Dankow, R., Majcher, M., Teichert, J., ... Bagnicka, E. (2015). Formation of volatile compounds in kefir made of goat and sheep milk with high polyunsaturated fatty acid content. *Journal of Dairy Science*, 98(10), 6692–6705.
- Cais-Sokolinska, D., Wojtowski, J., Pikul, J., & Lasik-Kurdys, M. (2017). Analysis of metabolic activity of lactic acid bacteria and yeast in model kefirs made from goat's milk and mixtures of goat's milk with mare's milk based on changes in electrical conductivity and impedance. *Mljekarstvo*, 67(4), 277–282.
- Carrillo, E., Prado-Gascó, V., Fiszman, S., & Varela, P. (2013). Why buying functional foods? Understanding spending behaviour through structural equation modelling. *Food Research International*, 50(1), 361–368.
- Ceballos, L. S., Morales, E. R., Adarve, G. T., Castro, J. D., Martínez, L., & Sampelayo, M. R. S. (2009). Composition of goat and cow milk produced under similar conditions and analyzed by identical methodology. *Journal of Food Composition and Analysis*, 22, 322–329.
- Champagne, C. P., Gomes da Cruz, A., & Daga, M. (2018). Strategies to improve the

- functionality of probiotics in supplements and foods. *Current Opinion in Food Science*, 22, 160–166.
- Chatchatee, P., Järvinen, K. M., Bardina, L., Vila, L., Beyer, K., & Sampson, H. A. (2001). Identification of IgE and IgG binding epitopes on β - and κ -casein in cow's milk allergic patients. *Clinical and Experimental Allergy*, 31(8), 1256–1262.
- Chen, J., Wang, J., Li, R., Lu, A., & Li, Y. (2015). Thermal and X-ray diffraction analysis of lactose polymorph. *Procedia Engineering*, 102, 372–378.
- Chen, L., Zhang, Q., Ji, Z., Shu, G., & Chen, H. (2018). Production and fermentation characteristics of angiotensin-I-converting enzyme inhibitory peptides of goat milk fermented by a novel wild *Lactobacillus plantarum* 69. *LWT-Food Science and Technology*, 91, 532–540.
- Clark, S., & García, M. B. (2017). A 100-year review: Advances in goat milk research. *Journal of Dairy Science*, 100(12), 10026–10044.
- Costa, M. P., Balthazar, C. F., Franco, R. M., Mársico, E. T., Cruz, A. G., & Conte, C. A. (2014). Changes on expected taste perception of probiotic and conventional yogurts made from goat milk after rapidly repeated exposure. *Journal of Dairy Science*, 97(5), 2610–2618.
- Costa, M. P., Frasco, B. S., Silva, A. C. O., Freitas, M. Q., Franco, R. M., & Conte-Junior, C. A. (2015). Cupuassu (*Theobroma grandiflorum*) pulp, probiotic, and prebiotic: Influence on color, apparent viscosity, and texture of goat milk yogurts. *Journal of Dairy Science*, 98(9), 5995–6003.
- Cunsolo, V., Fasoli, E., Saletti, R., Muccilli, V., Gallina, S., Righetti, P. G., & Foti, S. (2015). Zeus, Aesculapius, Amalthea and the proteome of goat milk. *Journal of Proteomics*, 128, 69–82.
- Domagala, J., Wszolek, M., & Dudzińska, A. (2012). Influence of fortification method and starter culture type on texture and microstructure of probiotic yoghurts prepared from goat's milk. *Milchwissenschaft*, 67(2), 172–176.
- Elsayed, S., Hill, D. J., & Do, T. V. (2004). Evaluation of the allergenicity and antigenicity of bovine-milk α 1-casein using extensively purified synthetic peptides. *Scandinavian Journal of Immunology*, 60(5), 486–493.
- Elwood, P. C., Pickering, J. E., Givens, D., & Gallacher, J. E. (2010). The consumption of milk and dairy foods and the incidence of vascular disease and diabetes: An overview of the evidence. *Lipids*, 45(10), 925–939.
- Esmerino, E. A., Castura, J. C., Ferraz, J. P., Tavares Filho, E. R., Silva, R., Cruz, A. G., ... Bolini, H. M. A. (2017). Dynamic profiling of different ready-to-drink fermented dairy products: A comparative study using Temporal Check-All-That-Apply (TCATA), Temporal Dominance of Sensations (TDS) and Progressive Profile (PP). *Food Research International*, 101, 249–258.
- Esmerino, E. A., Tavares Filho, E. R., Thomas Carr, B., Ferraz, J. P., Silva, H. L. A., Pinto, L. P. F., ... Bolini, H. M. A. (2017). Consumer-based product characterization using Pivot Profile, Projective Mapping and Check-all-that-apply (CATA): A comparative case with Greek yogurt samples. *Food Research International*, 99, 375–384.
- Fabersani, E., Grande, M. V., Coll Aráoz, M. V., Zannier, M. L., Sánchez, S. S., Grau, A., ... Honoré, S. M. (2018). Metabolic effects of goat milk yogurt supplemented with yacon flour in rats on high-fat diet. *Journal of Functional Foods*, 49, 447–457.
- FAOstat (2018). Food and Agriculture Organization of the United Nations database. From <<http://faostat3.fao.org/home/E>> Retrieved October 10, 2018.
- Fazilah, N. F., Ariff, A. B., Khayat, M. E., Rios-Solis, L., & Halim, M. (2018). Influence of probiotics, prebiotics, synbiotics and bioactive phytochemicals on the formulation of functional yogurt. *Journal of Functional Foods*, 48, 387–399.
- Fiocchi, A., Brozek, J., Schünemann, H., Bahna, S. L., Berg, A. V., Beyer, K., ... Vieths, S. (2010). World allergy organization (WAO) diagnosis and rationale for action against cow's milk allergy (DRACMA) guidelines. *Pediatric Allergy and Immunology*, 21(SUPPL. 21), 1–125.
- Flesch, A. G. T., Poziomyck, A. K., & Damin, D. D. C. (2014). The therapeutic use of synbiotics. *Arquivos Brasileiros de Cirurgia Digestiva*, 27(3), 206–209.
- Florowska, A., Krygier, K., Florowski, T., & Dżużewska, E. (2016). Prebiotics as functional food ingredients preventing diet-related diseases. *Food & Function*, 7(5), 2147–2155.
- Gésan-Guiziou, G. (2012). Liquid milk processing. In A. Y. Tamime (Ed.). *Membrane processing: Dairy and beverage applications* (pp. 128–142). Oxford, UK: Blackwell Publishing Ltd.
- Gibson, G. R., Hutkins, R., Sanders, M. E., Prescott, S. L., Reimer, R. A., Salminen, S. J., ... Reid, G. (2017). Expert consensus document: The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of prebiotics. *Nature Reviews Gastroenterology & Hepatology*, 14(8), 491–502.
- Gibson, G. R., & Roberfroid, M. B. (1995). Dietary modulation of the human colonic microbiota: Introducing the concept of prebiotics. *The Journal of Nutrition*, 125(6), 1401–1412.
- Gibson, G. R., Scott, K. P., Rastall, R. A., Tuohy, K. M., Hotchkiss, A., Dubert-Ferrandon, A., ... Buddington, R. (2010). Dietary prebiotics: Current status and new definition. *Food Science and Technology Bulletin: Functional Foods*, 7(1), 1–19.
- Giorgio, D., Di Trana, A., & Claps, S. (2018). Oligosaccharides, polyamines and sphingolipids in ruminant milk. *Small Ruminant Research*, 160, 23–30.
- Giroux, H. J., Veilleux, N., & Britten, M. (2018). Use of denatured whey protein in the production of artisanal cheeses from cow, goat and sheep milk. *Small Ruminant Research*, 161, 34–42.
- Granato, D., Branco, G. F., Cruz, A. G., Faria, J., de, A. F., & Shah, N. P. (2010). Probiotic dairy products as functional foods. *Comprehensive Reviews in Food Science and Food Safety*, 9(5), 455–470.
- Guo, M., Park, Y. W., Dixon, P. H., Gilmore, J. A., & Kindstedt, P. S. (2004). Relationship between the yield of cheese (Chevre) and chemical composition of goat milk. *Small Ruminant Research*, 52(1), 103–107.
- Haenlein, G. F. W. (2004). Goat milk in human nutrition. *Small Ruminant Research*, 51(2), 155–163.
- Hill, C., Guarnier, F., Reid, G., Gibson, G. R., Merenstein, D. J., Pot, B., ... Sanders, M. E. (2014). The International Scientific Association for Probiotics and Prebiotics consensus statement on the scope and appropriate use of the term probiotic. *Nature Reviews Gastroenterology & Hepatology*, 11(8), 506–514.
- Hodgkinson, A. J., Wallace, O. A. M., Boggs, I., Broadhurst, M., & Prosser, C. G. (2018). Gastric digestion of cow and goat milk: Impact of infant and young child in vitro digestion conditions. *Food Chemistry*, 245, 275–281.
- Ismail, M., Hamad, M., & Elraghy, E. M. (2018). Quality of Rayeb milk fortified with Tamr and honey. *British Food Journal*, 120(2), 499–514.
- Jandal, J. M. (1996). Comparative aspects of goat and sheep milk. *Small Ruminant Research*, 22, 177–185.
- Jirillo, F., Martemucci, G., D'Alessandro, A. G., Panaro, M. A., Cianciulli, A., Superbo, M., ... Magrone, T. (2010). Ability of goat milk to modulate healthy human peripheral blood lymphomonocyte and polymorphonuclear cell function: In vitro effects and clinical implications. *Current Pharmaceutical Design*, 16(7), 870–876.
- Kalyankar, S. D., Khedkar, C. D., & Patil, A. M. (2016). Goat milk. In B. Caballero, P. M. Finglas, & F. Toldrá (Eds.). *Encyclopedia of food and health* (pp. 256–260). Elsevier.
- Karimi, R., Azizi, M. H., Ghasemlou, M., & Vaziri, M. (2015). Application of inulin in cheese as prebiotic, fat replacer and texturizer: A review. *Carbohydrate Polymers*, 119, 85–100.
- Kinik, O., Kesenkas, H., Ergonul, P. G., Akan, E., Kinik, Ö., Kesenkas, H., ... Akan, E. (2017). The effect of using pro and prebiotics on the aromatic compounds, textural and sensorial properties of synbiotic goat cheese. *Mljekarstvo*, 67(1), 71–85.
- Kiskini, A., & Difilippo, E. (2013). Oligosaccharides in goat milk: Structure, health effects and isolation. *Cellular and Molecular Biology*, 59(1), 25–30.
- Koletzko, S., Niggemann, B., Arato, A., Dias, J. A., Heuschkel, R., Husby, S., ... Vandenplas, Y. (2012). Diagnostic approach and management of cow's-milk protein allergy in infants and children. *Journal of Pediatric Gastroenterology and Nutrition*, 55(2), 221–229.
- Korhonen, H. (2009). Milk-derived bioactive peptides: From science to applications. *Journal of Functional Foods*, 1(2), 177–187.
- Kullisaar, T., Songisepp, E., Mikelsaar, M., Zilmer, K., Vihalemm, T., & Zilmer, M. (2003). Antioxidative probiotic fermented goats' milk decreases oxidative stress-mediated atherogenicity in human subjects. Retrieved from *The British Journal of Nutrition*, 90(2), 449–456. <http://www.ncbi.nlm.nih.gov/pubmed/12908907>.
- Lara-Villoslada, F., Debras, E., Nieto, A., Concha, A., Gálvez, J., López-Huertas, E., ... Xaus, J. (2006). Oligosaccharides isolated from goat milk reduce intestinal inflammation in a rat model of dextran sodium sulfate-induced colitis. *Clinical Nutrition*, 25(3), 477–488.
- Lara-Villoslada, F., Olivares, M., Jiménez, J., Boza, J., & Xaus, J. (2004). Goat milk is less immunogenic than cow milk in a murine model of atopy. *Journal of Pediatric Gastroenterology and Nutrition*, 39(4), 354–360.
- Lima, E. L., Fernandes, J., Cardarelli, H. R., Lima, E. D. C., Fernandes, J. D., & Cardarelli, H. R. (2017). Optimized fermentation of goat cheese whey with *Lactococcus lactis* for production of antilisterial bacteriocin-like substances. *LWT-Food Science and Technology*, 84, 710–716.
- Lollo, P. C. B., Cruz, A. G., Morato, P. N., Moura, C. S., Carvalho-Silva, L. B., Oliveira, C. A. F., ... Amaya-Farfan, J. (2012). Probiotic cheese attenuates exercise-induced immune suppression in Wistar rats. *Journal of Dairy Science*, 95(7), 3549–3558.
- Lollo, P. C. B., de Moura, C. S., Morato, P. N., Cruz, A. G., Castro, W., de, D., Betim, C. B., & Amaya-Farfan, J. (2013). Probiotic yogurt offers higher immune-protection than probiotic whey beverage. *Food Research International*, 54(1), 118–124.
- Lollo, P. C. B., Morato, P. N., Moura, C. S., Almada, C. N., Felício, T. L., Esmerino, E. A., ... Cruz, A. G. (2015). Hypertension parameters are attenuated by the continuous consumption of probiotic Minas cheese. *Food Research International*, 76, 611–617.
- Machado, T. A. D. G., Oliveira, M. E. G., Campos, M. I. F., Assis, P. O. A., Souza, E. L., Madruga, M. S., ... Queiroga, R. C. R. E. (2017). Impact of honey on quality characteristics of goat yogurt containing probiotic *Lactobacillus acidophilus*. *LWT-Food Science and Technology*, 80, 221–229.
- Martharini, D., & Indratiningsih, I. (2017). Kualitas mikrobiologis dan kimiawi kefir susu kambing dengan penambahan *Lactobacillus acidophilus* FNCC 0051 dan tepung kulit pisang kepok (*Musa paradisiaca*). *Agrotech*, 37(1), 23.
- Martinez-Ferez, A., Rudloff, S., Guadix, A., Henkel, C. A., Pohlentz, G., Boza, J. J., ... Kunz, C. (2006). Goats' milk as a natural source of lactose-derived oligosaccharides: Isolation by membrane technology. *International Dairy Journal*, 16(2), 173–181.
- Martins, I. B. A., Deliza, R., Santos, K. M. O., Walter, E. H. M., Martins, J. M., & Rosenthal, A. (2018). Viability of probiotics in goat cheese during storage and under simulated gastrointestinal conditions. *Food and Bioprocess Technology*, 11(4), 853–863.
- Martins, A. A., Santos-Junior, V. A., Filho, E. R. T., Silva, H. L. A., Ferreira, M. V. S., Graça, J. S., ... Barros, M. E. (2018). Probiotic Prato cheese consumption attenuates development of renal calculi in animal model of urolithiasis. *Journal of Functional Foods*, 49, 378–383.
- Masotti, F., Cattaneo, S., Stuknytė, M., & De Noni, I. (2017). Technological tools to include whey proteins in cheese: Current status and perspectives. *Trends in Food Science and Technology*, 64, 102–114.
- Mayer, H. K., & Fiechter, G. (2012). Physicochemical characteristics of goat's milk in Austria-seasonal variations and differences between six breeds. *Dairy Science and Technology*, 92(2), 167–177.
- Meira, Q. G. S., Magnani, M., Medeiros Júnior, F. C., Queiroga, R. C. R. E., Madruga, M. S., Gullón, B., ... Souza, E. L. (2015). Effects of added *Lactobacillus acidophilus* and *Bifidobacterium lactis* probiotics on the quality characteristics of goat ricotta and their survival under simulated gastrointestinal conditions. *Food Research International*, 76, 828–838.
- Mensink, M. A., Frijlink, H. W., Maarschalk, K., & Hinrichs, W. L. J. (2015). Inulin, a flexible oligosaccharide I: Review of its physicochemical characteristics. *Carbohydrate Polymers*, 130, 405–419.
- Moraes, G. M. D., Abreu, L. R., Egito, A. S., Salles, H. O., Silva, L. M. F., Nero, L. A., ... Santos, K. M. O. (2017). Functional properties of *Lactobacillus mucosae* strains isolated

- from Brazilian goat milk. *Probiotics Antimicrob Proteins*, 9(3), 235–245.
- Moreno-Montoro, M., Olalla-Herrera, M., Rufian-Henares, J. A., Martínez, R. G., Miralles, B., Bergillos, T., ... Jauregi, P. (2017). Antioxidant, ACE-inhibitory and antimicrobial activity of fermented goat milk: Activity and physicochemical property relationship of the peptide components. *Food & Function*, 8(8), 2783–2791.
- Moschopoulou, E., Sakkas, L., Zoidou, E., Theodorou, G., Sgouridou, E., Kalathaki, C., ... Moatsou, G. (2018). Effect of milk kind and storage on the biochemical, textural and biofunctional characteristics of set-type yoghurt. *International Dairy Journal*, 77, 47–55.
- Moura, C. S., Lollo, P. C. B., Morato, P. N., Esmerino, E. A., Margalho, L. P., Santos-Junior, V. A., ... Amaya-Farfan, J. (2016). Assessment of antioxidant activity, lipid profile, general biochemical and immune system responses of Wistar rats fed with dairy dessert containing *Lactobacillus acidophilus* La-5. *Food Research International*, 90, 275–280.
- Muelas, R., Monllor, P., Romero, G., Sayas-Barbera, E., Navarro, C., Diaz, J. R., & Sendra, E. (2017). Milk technological properties as affected by including artichoke by-products silages in the diet of dairy goats. *Foods*, 6(12), 13.
- Navarro-Alarcón, M., Cabrera-Vique, C., Ruiz-López, M. D., Olalla, M., Artacho, R., Giménez, R., ... Bergillos, T. (2011). Levels of Se, Zn, Mg and Ca in commercial goat and cow milk fermented products: Relationship with their chemical composition and probiotic starter culture. *Food Chemistry*, 129(3), 1126–1131.
- Nozière, P., Graulet, B., Lucas, A., Martin, B., Grolier, P., & Doreau, M. (2006). Carotenoids for ruminants: From forages to dairy products. *Animal Feed Science and Technology*, 131(3–4), 418–450.
- O'Brien, K. V., Aryana, K. J., Prinyawiwatkul, W., Ordóñez, K. M. C., & Boeneke, C. A. (2016). The effects of frozen storage on the survival of probiotic microorganisms found in traditionally and commercially manufactured kefir. *Journal of Dairy Science*, 99(9), 7043–7048.
- Oliveira, E. W., Esmerino, E. A., Carr, B. T., Pinto, L. P. F., Silva, H. L. A., Pimentel, T. C., ... Freitas, M. Q. (2017). Reformulating Minas Frescal cheese using consumers' perceptions: Insights from intensity scales and check-all-that-apply questionnaires. *Journal of Dairy Science*, 100(8), 6111–6124.
- Oliveira, D. L., Wilbey, R. A., Grandison, A. S., Duarte, L. C., & Roseiro, L. B. (2012). Separation of oligosaccharides from caprine milk whey, prior to prebiotic evaluation. *International Dairy Journal*, 24(2), 102–106.
- Öztürk, H. I., Demirci, T., & Akin, N. (2018). Production of functional probiotic ice creams with white and dark blue fruits of *Myrtus communis*: The comparison of the prebiotic potentials on *Lactobacillus casei* 431 and functional characteristics. *LWT-Food Science and Technology*, 90, 339–345.
- Park, Y. W. (1994). Hypo-allergenic and therapeutic significance of goat milk. *Small Ruminant Research*, 14(2), 151–159.
- Park, Y. W., Juárez, M., Ramos, M., & Haenlein, G. F. (2007). Physico-chemical characteristics of goat and sheep milk. *Small Ruminant Research*, 68(1–2), 88–113.
- Paturi, G., Butts, C. A., Hedderley, D., Stoklosinski, H., Martell, S., Dinnan, H., & Carpenter, E. A. (2018). Goat and cow milk powder-based diets with or without prebiotics influence gut microbial populations and fermentation products in newly weaned rats. *Food Bioscience*. <https://doi.org/10.1016/j.fbio.2018.06.001> (in press).
- Pinto, L. P. F., Silva, H. L. A., Kuriya, S. P., Kuriya, S. P., Maçaira, P. M., Oliveira, F. L. C., ... Freitas, M. Q. (2018). Understanding perceptions and beliefs about different types of fermented milks through the application of projective techniques: A case study using Haire's shopping list and free word association. *Journal of Sensory Studies*, 33(3), e12326.
- Prasanna, P. H. P., & Charalampopoulos, D. (2018). Encapsulation of *Bifidobacterium longum* in alginate-dairy matrices and survival in simulated gastrointestinal conditions, refrigeration, cow milk and goat milk. *Food Bioscience*, 21, 72–79.
- Pulina, G., Milán, M. J., Lavín, M. P., Theodoridis, A., Morin, E., Capote, J., ... Caja, G. (2018). Invited review: Current production trends, farm structures, and economics of the dairy sheep and goat sectors. *Journal of Dairy Science*, 101(8), 6715–6729.
- Quintana, A. V., Olalla-Herrera, M., Ruiz-Lopez, M. D., Moreno-Montoro, M., & Navarro-Alarcón, M. (2015). Study of the effect of different fermenting microorganisms on the Se, Cu, Cr, and Mn contents in fermented goat and cow milks. *Food Chemistry*, 188, 234–239.
- Quiros, A., Hernandez-Ledesma, B., Ramos, M., Amigo, L., Recio, I., Quirós, A., ... Recio, I. (2005). Angiotensin-converting enzyme inhibitory activity of peptides derived from caprine kefir. *Journal of Dairy Science*, 88(10), 3480–3487.
- Ranadheera, C., Evans, C. A., Adams, M. C., & Baines, S. K. (2012). Probiotic viability and physico-chemical and sensory properties of plain and stirred fruit yogurts made from goat's milk. *Food Chemistry*, 135(3), 1411–1418.
- Ranadheera, C. S., Evans, C. A., Adams, M. C., & Baines, S. K. (2013). Production of probiotic ice cream from goat's milk and effect of packaging materials on product quality. *Small Ruminant Research*, 112(1), 174–180.
- Ranadheera, C. S., Evans, C. A., Adams, M., & Baines, S. K. (2016). Co-culturing of probiotics influences the microbial and physico-chemical properties but not sensory quality of fermented dairy drink made from goats' milk. *Small Ruminant Research*, 136, 104–108.
- Ranadheera, C. S., Naumovski, N., & Ajlouni, S. (2018). Non-bovine milk products as emerging probiotic carriers: Recent developments and innovations. *Current Opinion in Food Science*, 22, 109–114.
- Raynal-Ljutovac, K., Lagriffoul, G., Paccard, P., Guillet, I., & Chilliard, Y. (2008). Composition of goat and sheep milk products: An update. *Small Ruminant Research*, 79(1), 57–72.
- Rodrigues, R., Guerra, G., Soares, J., Santos, K., Rolim, F., Assis, P., ... Queiroga, R. (2018). *Lactobacillus rhamnosus* EM1107 in goat milk matrix modulates intestinal inflammation involving NF- κ B p65 and SOCs-1 in an acid-induced colitis model. *Journal of Functional Foods*, 50, 78–92.
- Ruiter, B., Trégoat, V., M'Rabet, L., Garssen, J., Bruijnzeel-Koomen, C. A., Knol, E. F., & Van Hoven, E. (2006). Characterization of T cell epitopes in α s1-casein in cow's milk allergic, atopic and non-atopic children. *Clinical and Experimental Allergy*, 36(3), 303–310.
- Salva, S., Nunez, M., Villena, J., Ramon, A., Font, G., & Alvarez, S. (2011). Development of a fermented goats' milk containing *Lactobacillus rhamnosus*: In vivo study of health benefits. *Journal of the Science of Food and Agriculture*, 91(13), 2355–2362.
- Salva, S., Villena, J., & Alvarez, S. (2010). Immunomodulatory activity of *Lactobacillus rhamnosus* strains isolated from goat milk: Impact on intestinal and respiratory infections. *International Journal of Food Microbiology*, 141(1–2), 82–89.
- Salvatore, E., Pes, M., Mazzarello, V., & Pirisi, A. (2014). Replacement of fat with long-chain inulin in a fresh cheese made from caprine milk. *International Dairy Journal*, 34(1), 1–5.
- Sant'Ana, A. M. S., Bezerril, F. F., Madruga, M. S., Batista, A. S. M., Magnani, M., Souza, E. L., & Queiroga, R. (2013). Nutritional and sensory characteristics of Minas fresh cheese made with goat milk, cow milk, or a mixture of both. *Journal of Dairy Science*, 96(12), 7442–7453.
- Sant'Anna, V., Gurak, P. D., Ferreira Marczak, L. D., & Tessaro, I. C. (2013). Tracking bioactive compounds with colour changes in foods – A review. *Dyes and Pigments*, 98(3), 601–608.
- Santos, K. M. O., Bomfim, M. A. D., Vieira, A. D. S., Benevides, S. D., Saad, S. M. I. L., Buriti, F. C. A., & Egito, A. S. (2012). Probiotic caprine Coalho cheese naturally enriched in conjugated linoleic acid as a vehicle for *Lactobacillus acidophilus* and beneficial fatty acids. *International Dairy Journal*, 24(2), 107–112.
- Schulmeister, U., Hochwallner, H., Swoboda, I., Focke-Tejkl, M., Geller, B., Nystrand, M., ... Spitzauer, S. (2009). Cloning, expression, and mapping of allergenic determinants of S1-casein, a major cow's milk allergen. *The Journal of Immunology*, 182(11), 7019–7029.
- Setyawardani, T., Rahardjo, A. H. D., & Sulistyowati, M. (2017). Chemical characteristics of goat cheese with different percentages of mixed indigenous probiotic culture during ripening. *Media Peternakan*, 40(1), 55–62.
- Shafi, A., Farooq, U., Akram, K., Hayat, Z., & Murtaza, M. A. (2014). Prevention and control of diseases by use of pro- and prebiotics (synbiotics). *Food Reviews International*, 30(4), 291–316.
- Sharma, K., Mahajan, R., Attri, S., & Goel, G. (2017). Selection of indigenous *Lactobacillus paracasei* CD4 and *Lactobacillus gastricus* BTM 7 as probiotic: Assessment of traits combined with principal component analysis. *Journal of Applied Microbiology*, 122(5), 1310–1320.
- Silanikove, N., Leitner, G., Merin, U., & Prosser, C. G. (2010). Recent advances in exploiting goat's milk: Quality, safety and production aspects. *Small Ruminant Research*, 89(2–3), 110–124.
- Silva, H. L. A., Balthazar, C. F., Esmerino, E. A., Vieira, A. H., Cappato, L. P., Neto, R. P. C., ... Cruz, A. G. (2017). Effect of sodium reduction and flavor enhancer addition on probiotic Prato cheese processing. *Food Research International*, 99, 247–255.
- Silva, P. D. L., Bezerra, M. F., Santos, K. M. O., & Correia, R. T. P. (2015). Potentially probiotic ice cream from goat's milk: Characterization and cell viability during processing, storage and simulated gastrointestinal conditions. *LWT – Food Science and Technology*, 62(1, Part 2), 452–457.
- Silveira, E. O., Lopes Neto, J. H., Silva, L. A., Raposo, A. E. S., Magnani, M., & Cardarelli, H. R. (2015). The effects of inulin combined with oligofructose and goat cheese whey on the physicochemical properties and sensory acceptance of a probiotic chocolate goat dairy beverage. *LWT – Food Science and Technology*, 62(1, Part 2), 445–451.
- Simos, Y., Metsios, A., Verginadis, I., D'Alessandro, A. G., Louidice, P., Jirillo, E., ... Karkabounas, S. (2011). Antioxidant and anti-platelet properties of milk from goat, donkey and cow: An in vitro, ex vivo and in vivo study. *International Dairy Journal*, 21(11), 901–906.
- Simsek, S., Sánchez-Rivera, L., El, S. N., Karakaya, S., & Recio, I. (2017). Characterisation of in vitro gastrointestinal digests from low fat caprine kefir enriched with inulin. *International Dairy Journal*, 75, 68–74.
- Soares, E. K. B., Esmerino, E. A., Ferreira, M. V. S., da Silva, M. A. A. P., Freitas, M. Q., & Cruz, A. G. (2017). What are the cultural effects on consumers' perceptions? A case study covering coalho cheese in the Brazilian northeast and southeast area using word association. *Food Research International*, 102, 553–558.
- Songisepp, E., Kals, J., Kullisaar, T., Mändar, R., Hütt, P., Zilmer, M., & Mikelsaar, M. (2005). Evaluation of the functional efficacy of an antioxidative probiotic in healthy volunteers. *Nutrition Journal*, 4(1), 22.
- Sperry, M. F., Silva, H. L. A., Balthazar, C. F., Esmerino, E. A., Verruck, S., Prudencio, E. S., ... Cruz, A. G. (2018). Probiotic Minas Frescal cheese added with L. casei 01: Physicochemical and bioactivity characterization and effects on hematological/biochemical parameters of hypertensive overweighted women – A randomized double-blind pilot trial. *Journal of Functional Foods*, 45, 435–443.
- Spurgin, P., Mueller, H., Walter, M., Schiltz, E., & Forster, J. (1996). Allergenic epitopes of bovine α s1-casein recognised by human IgE and IgG. *Allergy*, 306–312.
- Srinivasan, M., Sudheer, A., & Menon, V. (2007). Ferulic acid: Therapeutic potential through its antioxidant property. *Journal of Clinical Biochemistry and Nutrition*, 40, 92–100.
- Swaigood, H. E. (2008). Characteristics of milk. In O. R. Damodaran, S. Parkin, & K. L. Fennema (Eds.). *Fennema's food chemistry* (pp. 886–920). (4th ed.). Boca Raton, FL: CRC Press.
- Tamime, A. Y., Wszolek, M., Božanić, R., & Özer, B. (2011). Popular ovine and caprine fermented milks. *Small Ruminant Research*, 101(1), 2–16.
- Taverniti, V., & Guglielmetti, S. (2011). The immunomodulatory properties of probiotic microorganisms beyond their viability (Good probiotics: Proposal of paraprobiotic concept). *Genes and Nutrition*, 6(3), 261–274.
- Taylor, M. W., & MacGibbon, A. K. H. (2011). Milk lipids: General characteristics. In J. W. Fuquay, P. F. Fox, & P. L. H. McSweney (Eds.). *Encyclopedia of dairy sciences* (pp. 3:649–3:654). (2nd ed.). London, UK: Elsevier Ltd.

- Torres, F. R., Esmerino, E. A., Carr, B. T., Ferrão, L. L., Granato, D., Pimentel, T. C., ... Cruz, A. G. (2017). Rapid consumer-based sensory characterization of requeijão cremoso, a spreadable processed cheese: Performance of new statistical approaches to evaluate check-all-that-apply data. *Journal of Dairy Science*, 100(8), 6100–6110.
- Tsilingiri, K., & Rescigno, M. (2013). Postbiotics: What else? *Beneficial Microbes*, 4(1), 101–107.
- Varga, L., Süle, J., & Nagy, P. (2014). Short communication: Survival of the characteristic microbiota in probiotic fermented camel, cow, goat, and sheep milks during refrigerated storage. *Journal of Dairy Science*, 97(4), 2039–2044.
- Vedran, S., Rajka, B., Jovica, H., Judit, R. S., Mirela, L., & Vinko, K. (2010). Nutritional and therapeutic value of fermented caprine milk. *International Journal of Dairy Technology*, 63(2), 171–189.
- Verhoeckx, K. C. M., Vissers, Y. M., Baumert, J. L., Faludi, R., Feys, M., Flanagan, S., ... Kimber, I. (2015). Food processing and allergenicity. *Food and Chemical Toxicology*, 80, 223–240.
- Verruck, S., Carvalho, M. W., Liz, G. R., Amante, E. R., Vieira, C. R. W., Amboni, R., & Prudencio, E. S. (2017). Survival of *Bifidobacterium* BB-12 microencapsulated with full-fat goat's milk and prebiotics when exposed to simulated gastrointestinal conditions and thermal treatments. *Small Ruminant Research*, 153(February), 48–56.
- Verruck, S., de Liz, G. R., Dias, C. O., de Mello Castanho Amboni, R. D., & Prudencio, E. S. (2018). Effect of full-fat goat's milk and prebiotics use on *Bifidobacterium* BB-12 survival and on the physical properties of spray-dried powders under storage conditions. *Food Research International*. <https://doi.org/10.1016/J.FOODRES.2018.10.042>.
- Verruck, S., Santana, F., Müller, C., & Prudencio, E. S. (2018). Thermal and water sorption properties of *Bifidobacterium* BB-12 microcapsules obtained from goat's milk and prebiotics. *LWT – Food Science and Technology*, 98, 314–332.
- Vila, L., Beyer, K., Järvinen, K. M., Chatchatee, P., Bardina, L., & Sampson, H. A. (2001). Role of conformational and linear epitopes in the achievement of tolerance in cow's milk allergy. *Clinical and Experimental Allergy*, 31(10), 1599–1606.
- Wang, W., Bao, Y., Hendricks, G., & Guo, M. (2011). Consistency, microstructure and probiotic survivability of goats' milk yoghurt using polymerized whey protein as a co-thickening agent. *International Dairy Journal*, 24(2), 113–119.
- Wang, H., Wang, C. N., Wang, M., & Guo, M. R. (2017). Chemical, physiochemical, and microstructural properties, and probiotic survivability of fermented goat milk using polymerized whey protein and starter culture kefir mild 01. *Journal of Food Science*, 82(11), 2650–2658.
- Yazdi, M. K. S., Davoodabadi, A., Zarin, H. R. K., Ebrahimi, M. T., & Dallal, M. M. S. (2017). Characterisation and probiotic potential of lactic acid bacteria isolated from Iranian traditional yogurts. *Italian Journal of Animal Science*, 16(2), 185–188.
- Zhang, W. Q., Ge, W. P., Yang, J., Xue, X. C., Wu, S. Z., Chen, Y., & Qin, L. H. (2015). Comparative of *in vitro* antioxidant and cholesterol-lowering activities of fermented goat & cow milk. *Resources Environment and Engineering*, 417–424.