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Protective, technological, and functional properties of select autochthonous lactic acid bacteria from goat dairy products

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Goat milk and its derived products have high nutritional value. To increase their production, it is necessary to increase food safety, to improve their flavor, and to potentiate their functional value. Lactic acid bacteria (LAB) can help in the development of products with these characteristics. LAB have a long history of use in fermented foods, improving their protective, technological, and functional properties. Protective properties refer to the production of organic acids, diacetyl, hydrogen peroxide, and bacteriocins. Acidifying activity and diacetyl, exopolysaccharide (EPS), and enzyme production are desirable technological properties. In terms of functional properties, LAB can contribute to the release and/or production of compounds such as EPS, vitamins, bioactive peptides, bioactive lipids, and enzymes in food. To obtain all these benefits, the choice of LAB strain is crucial, as select autochthonous LAB have all of these properties. Generally, fermented foods elaborated with autochthonous LAB have better sensorial acceptance. These cultures might consolidate typical products, differentiate and influence the region's economy, and assist small producers and cooperatives that do not have access to industrial processing. This review aims to explore the protective, technological, and functional properties of select autochthonous LAB from goat dairy products.

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Introduction

The consumption of goat milk and products has increased in recent years. Goat milk is considered nutritional and therapeutic. A major factor in the consumption of goat milk and its derived products are their beneficial effects on human health. However, goat milk and its derivatives are associated with low sensorial acceptance and microbiological quality [1–3].

In arid and semiarid regions, where there is a greater concentration of goat herds, milk production is still in development, and it is necessary to increase the safety and acceptability of these products [1,4,5]. In relation to the low microbiological quality, goat milk presents a high bacterial count and is a vehicle for certain pathogens, such as *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella* species [4,6–8]. The types of bacteria in milk can present risks to consumers and can influence the manufacturing of milk products and their expiration dates [9].

The diversification of goat milk is essential but is dependent on the development of new and valuable products [3,10]. Everywhere in the world, consumers traditionally avoid goat milk due to its strong flavor. Some countries in Europe sell a blend of goat and cow milk to remedy this problem. Most milk results in the generation of fermented products like cheese and yogurt; during fermentative processes, goat milk loses some of its characteristic flavor [11,12]. The Northeast Region of Brazil, where the largest herds of goats are concentrated, is no exception; in Brazil, goat milk does not present good acceptability by consumers and is more often used to produce cheese and fermented goat milk [13,14].

An alternative to increase the safety, flavor, and functional value of goat milk products is the insertion of lactic acid bacteria (LAB). These microorganisms have the ability to produce a number of desirable substances that can improve the flavor, texture, nutritional value, shelf life, and innocuity of food. Autochthonous LAB from goat dairy products can be used as starter cultures and are more efficient than commercial cultures. Autochthonous cultures dominate and remain in their natural environment, in this case, food; therefore, they can produce antimicrobial compounds and have adequate metabolic activity, both of which play key roles in flavor formation and potential functional properties in the food matrix (Table 1). These autochthonous cultures are important in the Protected Denomination of Origin (PDO) of many products [15••,16]. In Brazil, they contribute to the Geographical Indication (IG) and quality of handmade products. This review summarizes the protective,

Table 1

Examples of autochthonous LAB from goat dairy products and their properties

Autochthonous LAB	Origin	Role	Production	Reference
Lc. lactis subsp. *lactis* (3LC39 e 1LC18)	Goat milk	Protective	Organic acids	[51]
Lb. plantarum (LbMS16 and LbMS21)	Goat milk			[87]
Lc. lactis subsp. *lactis* (TAUL 95, TAUL 119 and TAUL 1292)	Goat cheese			[88]
Lc. lactis subsp. *lactis* biovar *diacetylactis* 19 MMC	Goat milk		Diacetyl	[64]
Lc. lactis subsp. *lactis* var. *diacetylactis* (TAUL 13), *Ln. mesenteroides* subsp. *dextranicum* (TAUL 1368 and 1795), *Ln. mesenteroides* subsp. *mesenteroides* (TAUL 34), *Lb. plantarum* (TAUL 1539) and *Lb. brevis* (TAUL 68 and TAUL 1267)	Goat cheese		Hydrogen peroxide	[89]
Lc. sakei GM3	Goat milk		Bacteriocins	[90]
Lc. lactis subsp. *lactis (*BGZLM1) and *Lc. lactis* subsp. *lactis* (BGMN1596)	Goat cheese		Bacteriocins	[33]
E. faecium (UNIVASF CAP 29)	Goat milk	Technological	EPS	[27]
Ln. mesenteroides subsp. *mesenteroides* (TAU 34), *L. casei* subsp. *casei* (TAUL 1506, 1508,1522)	Goat cheese		Aminopeptidases	[88]
Lb. casei subsp. *casei* IFPL 731	Goat cheese		Peptidases	[91]
Lb. fermentum CRL1446	Goat cheese		Esterases	[85••]
Lb. fermentum CRL1446	Goat cheese	Functional	CLA	[92]
Lb. casei subsp. *casei* (LCB17), *Lb. casei* subsp. *rhamnosus* (LCB26)	Goat milk		BSH	[93]
Lb.plantarum (TAUL 1736)	Goat cheese		β-Galactosidase	[94]
Lc. lactis subsp. *cremoris* (TAUL 1351)	Goat cheese		α-Galactosidase	[88]
Lb. plantarum and *Lb. paracasei*	Goat cheese		Phytase	[39]
Lb. fermentum CRL1446	Goat cheese		Feruloyl esterases	[95]

Lactobacillus = *Lb.*; *Lactococcus* = *Lc.*; *Leuconostoc* = *Ln.*

technological, and functional properties of cultures through select autochthonous LAB from goat dairy products.

Protective properties of LAB

Goat milk and its derivatives are vehicles for pathogens [2,17]. The use of autochthonous LAB is an effective biological method to control foodborne pathogens in foods such as goat cheese [18] and fermented goat milk [19••]. In products, LAB can present naturally or be added. LAB produce certain compounds during fermentation, such as organic acids, diacetyl, hydrogen peroxide (H_2O_2), and bacteriocins. These metabolic products have positive effects on the taste, smell, color, and texture of fermented foods, and they may also have beneficial side effects, such as extending shelf life and inhibiting the growth of pathogenic organisms [20,21].

The decreased pH value and antibacterial activity of organic acids produced by LAB are the main mechanisms for the biopreservation of fermented foods [21]. LAB are able to produce a series of organic acids, such as lactic, acetic, succinic, propionic, formic, and butyric acids. In addition, LAB perform the fermentation of sugar to produce organic acids, which decrease the pH value of substrate. Low pH makes organic acids liposoluble, allowing them to interfere with the maintenance of the cell membrane potential. This causes them to inhibit active transport, break through the cell membrane, and reach the cytoplasm, resulting in the reduction of intracellular pH and the inhibition of various metabolic functions of pathogens. This inhibitory effect comprises Gram-positive and Gram-negative bacteria as well as yeast and molds [22•,23,24].

The production of organic acid varies significantly depending on the LAB strain and the growth medium used [22•]. Goat milk and its derived products are a source of LAB with an acidifying capacity. In agreement, Torno *et al.* [25] reported the domain of the *Lactococcus lactis* subspecies *lactis* in goat milk to have good acid production. Picon *et al.* [26•] affirmed that *Lactococcus* isolated from goat cheese decreased milk's pH value to 5.3 after incubation for 6 hours at 30°C and produced antimicrobial compounds. Autochthonous LAB from goat milk with an acidifying capacity also reduced the population of *Escherichia coli* [27] and *Salmonella* [18] in goat cheese.

Diacetyl (2,3-butanedione) is a volatile metabolite for citrate metabolism produced by LAB [28,29]. It can also inhibit pathogenic microorganisms by penetrating the targeted bacterial membranes and interfering with essential metabolic functions. The antagonistic activity of diacetyl occurs through the blocking of the catalytic site of the enzymes responsible for arginine utilization, rendering the cells incapable of synthesizing essential proteins [30,31]. Diacetyl produced by autochthonous LAB from goat milk and cheese was reported by Ferrari *et al.* [18], Almeida Junior *et al.* [27], Taboada *et al.* [32], Terzic-Vidojevic *et al.* [33], Bontinis *et al.* [34], Cabral *et al.* [35] and Oliszewski *et al.* [36].

LAB that possess flavoprotein oxidases may produce and accumulate (H_2O_2) in the presence of molecular oxygen