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Lactoperoxidase system in the dairy industry: Challenges and opportunities

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Abstract: The objective of this review was to search the literature for studies on the lactoperoxidase system (LPS) as milk natural preservation, action mechanisms, usage methods and perspectives for the dairy industry. A comprehensive literature review approach was conducted for collecting evidence in scientific publications. The biological properties of milk promote the development of microorganisms which compromise its quality, therefore demanding the use of techniques for preserving the milk matrix from its collection until processing. Within this context, LPS could represent an alternative to guarantee the safety of this food in areas where refrigeration is not possible; in addition, studies on applying this system in the dairy industry have been explored, as is the case in the test for verifying pasteurisation efficiency according to determining the lactoperoxidase enzyme activity. Natural antimicrobial properties of LPS make it a promising alternative for the industrial preservation and processing of milk, especially when considering the current quality standard demanded by the market. However, the potential of LPS as a biopreservative is still little technically and scientifically explored, which implies the need to develop new studies.

Keywords: antimicrobial system; conservation; enzyme; milk quality; raw milk

As the demand for dairy products continues increasing, the quality of the raw material must be considered as a highly relevant factor, considering that the consumer market is increasingly demanding in relation to the quality of the products it consumes, prioritising those which minimise health risks.

Among several essential requirements for milk quality, one can highlight the high microbiological count as a factor which can negatively influence technologi-

cal processing. This reduces industrial performance, causes changes that reduce shelf life and changes the sensory characteristics of derived products. In addition, high contamination by microorganisms poses health risk to consumers due to the action of pathogens (Vilar et al. 2012).

Due to its chemical composition, milk has favourable conditions for developing deteriorating microorganisms which affect its quality, making it a perishable

food (De Silva et al. 2016). Thus, milk conservation and handling measures are necessary in order to ensure the characteristics and stability of the product from milking to processing.

Lactoperoxidase (LP) has wide applications in the dairy industry, particularly in raw milk preservation in situations where prompt refrigeration is difficult, and especially in developing countries (Jooyandeh et al. 2011; Aprodu et al. 2014; Lara-Aguilar & Alcaine 2019).

The lactoperoxidase system (LPS) is a non-specific mechanism for protecting the mammary gland which is present in all mammals and prolongs milk shelf life (Arefin et al. 2017). This system involves a series of chemical reactions and consists of LP, thiocyanate ion (SCN^-) derived from liver metabolism, and hydrogen peroxide (H_2O_2) derived from cell metabolism (Sermon et al. 2005; Golmohamadi et al. 2016). These three components (LP, SCN^- and H_2O_2) are indispensable to activate the LPS. Its activation is represented by SCN^- oxidation by H_2O_2 , and this oxidation is catalysed by LP. The products of this reaction are hypothiocyanic acid (HOSCN) and hypothiocyanate ion (OCSN^-), the compounds that have antimicrobial characteristics (Seifu et al. 2005; Bafort et al. 2014; Al-Baarri et al. 2018). These reactions are described in Figure 1.

The antimicrobial action of LPS results in the oxidation of sulfhydryl groups of various enzymes and other proteins which are essential to microbial metabolism (Reiter & Harnulv 1984; CAC 1991). This action alters the metabolism of bacteria and causes lesions or changes in the various structures of the bacterial cell such as cell wall, active and passive transport system, glycolytic enzymes and nucleic acids, which consequently interferes with the microorganism ability to multiply. This may lead to an increase in the amount of milk that

could be available for marketing in acceptable quality, with benefits both milk producers and consumers (Aprodu et al. 2014; Lara-Aguilar & Alcaine 2019).

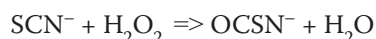
Alternative methods have been used and studied in order to promote milk stabilisation at room temperature and also to extend the shelf life of pasteurised milk (Stamenova & Hoffmann 2016). One of the ways of conserving milk is through the activity of natural antimicrobials existing in milk called LPS, which maintains milk integrity (Jooyandeh et al. 2011; Urtasun et al. 2017; Lara-Aguilar & Alcaine 2019). Based on this information, the objective of this review was to perform a survey of the literature on the LPS as a form of natural (milk) conservation, its related concepts, action mechanisms, usage methods and perspectives for the dairy industry.

Lactoperoxidase (LP)

LP is a member of the peroxidase family, a group of natural enzymes which are widely distributed in nature and found in secretions of mammary glands (colostrum and milk), salivary and lacrimal glands (Sharma et al. 2013; Bafort et al. 2014; Sousa et al. 2014). It is synthesised in the gastrointestinal tract of infants, and it is also the enzyme which is synthesised in the greatest quantity by the mammary gland, having the function of protecting the glands against pathogens (Jafary et al. 2013; Sharma et al. 2013). Thus, raw milk which has greater LP activity, may have its shelf life increased. This fact can be very important in places which have a deficiency or impossibility of quick milk cooling/refrigeration after obtaining it (Ndambi et al. 2008).

There are more than 60 different types of enzymes in milk. Thus, many studies have been conducted in order to determine the biological or physiological role

First oxidation pathway of the thiocyanate ion



Second oxidation pathway of the thiocyanate ion

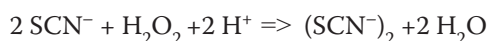


Figure 1. Lactoperoxidase-catalysed thiocyanate oxidation reactions (Thom as 1985)

SCN^- – thiocyanate ion; OCSN^- – hypothiocyanate ion; HOSCN – hypothiocyanic acid

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of these compounds, as well as to verify their relevance in food quality, technological processing and product stability (Andrews et al. 1991).

LP is mainly synthesised in the mammary gland by polymorphonuclear leukocytes and constitutes one of the main proteins of whey, presenting the superior average activity to the biological needs required for optimal redox catalysis to happen (Fonteh et al. 2002). The main biological role of LP is associated with the protection of the milk itself, the mammary gland and the intestinal tract of infants against pathogenic microorganisms which may be present in milk (Atasever et al. 2013).

Concentration of LP in milk. There is a variation between species in terms of units of enzymatic activity (UA mL⁻¹) from 0.14 to 4.45, with an average of 1.4 UA mL⁻¹ in cows; however, the minimum concentration for bactericidal action is 0.02 UA mL⁻¹ (Seifu et al. 2005). Regarding the concentrations of the substrates, reactive oxygen and thiocyanate ions are between 0.20 and 0.25 mmol L⁻¹ when the maximum activity of the enzyme is reached, as established by FAO/WHO in the CAC (1991).

LP is one abundant enzyme in bovine milk (Jafary et al. 2013). Its concentration in bovine milk is about 30 mg L⁻¹, corresponding to about 1% of whey protein (Reiter 1985; Seifu et al. 2005). The LP content in bovine colostrum is low; however, it increases as the days go by, reaching its maximum concentration between 3 and 5 days postpartum (Reiter 1985; Kussendrager & Van Hooijdonk 2000). Variations in enzyme concentration may depend on the oestrous cycle stage of the cow, its diet and the breed (Kussendrager & Van Hooijdonk 2000). There is also a variation in the enzymatic activity among the species according to Table 1.

Chemical properties of LP. LP is one of the most heat-stable enzymes, which is why it can be used to identify efficiency in the pasteurisation process (Boulares et al. 2011; Dumitrascu et al. 2012). It is resistant to acidity up to a pH equal to 3, and also to the proteolytic action of gastric juice (Kussendrager & Van Hooijdonk 2000; Ozer 2014). However, it is irreversibly inactivated by an excess of H₂O₂, and it is also inactivated by light in the presence of riboflavin and oxygen (Kussendrager & Van Hooijdonk 2000) or by excessive microorganism growth.

A study by Marks et al. (2001) confirms the fact that normal milk pasteurisation does not disable LP in milk. They reported that an active LP system was found after pasteurisation of cow's milk at 72 °C for 15 sec which is

capable of maintaining the milk quality inoculated with *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Streptococcus thermophilus*.

The lactoperoxidase system (LPS)

The LPS is an enzymatic and antibacterial system which consists of the enzyme LP, SCN⁻ resulting from hepatic metabolism, and H₂O₂ from cellular metabolism (Tayefi-Nasrabadi et al. 2011; Golmohamadi et al. 2016).

The system is activated through an oxidation reaction of SCN⁻ by H₂O₂ and catalysed by LP. The products deriving from this process are hypothiocyanic acid (HOSCN) and the hypothiocyanate ion (OSCN⁻), which has a broad spectrum of antimicrobial effects against bacteria, fungi and viruses (Bafort et al. 2014; Golmohamadi et al. 2016; Al-Baarri et al. 2018). LP is an oxidoreductase and catalyses the oxidation of SCN⁻ at the expense of H₂O₂ to generate the antimicrobial product of OSCN⁻ (Sousa et al. 2014; Urtasun et al. 2017; Al-Baarri et al. 2018).

Thiocyanate ion. SCN⁻ is widely distributed in animal tissues and secretions, being present in the mammary, thyroid and salivary glands, in organs such as stomach and kidneys, and in biological fluids such as plasma and brain fluid (Fsanj 2002; Wijkstrom-Frei et al. 2003; Narkowicz et al. 2018).

The concentration of SCN⁻ in bovine milk reflects serum levels in blood, varying according to the breed, species, udder health, type of diet, season and geographic regions (Kussendrager & Van Hooijdonk 2000; Yong et al. 2017). The concentration of SCN⁻ present in the animal's metabolism partly depends on the food supplied, with there being two important dietary sources that give rise to SCN⁻: glucosinolates and cyanogenic glycosides (Yong et al. 2017).

Fweja et al. (2008) reported that fresh cow's milk contains 1 to 35 mg of SCN⁻ per litre, which is not always sufficient to activate the LPS. About 10 mg of SCN⁻ per litre is added to raw milk for exogenous activation of the system, as established by CAC (2004).

Table 1. Lactoperoxidase (LP) activity in different species

Species	Enzymatic activity (Unit mL ⁻¹)
Cattle	1.4–4.45
Sheep	0.4–2.38
Goat	1.55
Buffalo	0.9
Human	0.06–0.97

Source: Adapted from Seifu et al. (2005)

The excess SCN^- in the body can produce goitres because it interferes with iodine metabolism, but according to Yong et al. (2017), the amount of milk ingested and SCN^- concentration does not reach the necessary limits to affect the thyroid function. More than 20 ppm in human plasma would be required to interfere with iodine metabolism (FAO/WHO 2005).

The oxidation of SCN^- also forms intermediate products (reactive oxygen species), but these are very unstable in milk, especially under high temperatures. Thus, the heat treatment at 65 °C ensures that such elements are not present in the milk at the time of consumption or in the production of dairy products (Reiter & Hamulv 1984; Ponce 2007).

Hydrogen peroxide. H_2O_2 is an oxidising agent with a bactericidal effect and is not normally detected in raw milk (Pruitt & Kamau 1991; FAO 1999). According to Marshall et al. (1982), there are bacteria which produce H_2O_2 in saliva and gastric juice, but its presence is difficult to verify due to its rapid absorption.

H_2O_2 is the third component of the LPS. It can be endogenously generated by polymorphonuclear leukocytes in the phagocytosis process, and it is also produced by many lactobacilli, lactococci and streptococci in sufficient quantity to activate the LPS under aerobic conditions (Jooyandeh et al. 2011).

H_2O_2 is naturally found in raw milk, but in very low concentrations (Arefin et al. 2017), thus requiring it to be exogenously added in solution or the solid form so that LPS activity remains active (Ozer et al. 2003). H_2O_2 can also be provided through the action of enzymes such as glucose oxidase or xanthine oxidase (Kussendrager & Van Hooijdonk 2000).

According to the criteria established by CAC (2004), 8.5 ppm of H_2O_2 should be added for exogenous activation of the LPS.

H_2O_2 is highly toxic to mammalian cells. However, the cells are protected against this toxicity when at low concentrations and in the presence of LP and SCN^- (Pruitt & Kamau 1991; Jooyandeh et al. 2011). Excess peroxide inhibits the action of the enzyme LP, with concentrations above 60 mM L^{-1} of H_2O_2 inactivating the enzyme (Perez 1987).

H_2O_2 is the only approved additive for preserving milk in the absence of refrigeration and can be added at a concentration of 100–800 ppm (100–800 mg L^{-1}) (FAO 1957; IDF 1988). According to Bjorck (1992), the activation of the LP system requires minimal amounts of H_2O_2 . The criterion established by the CAC (1991) for exogenous activation of the LP system is the addition of 8 mg L^{-1} of H_2O_2 . This concentration

is one hundred times lower than that used to conserve milk using only H_2O_2 (500–800 mg L^{-1}).

H_2O_2 is highly toxic to mammalian cells. However, mammalian cells are protected against this toxicity when it is at low concentrations and in the presence of LP and SCN^- (Pruitt & Kamau 1991), since H_2O_2 disappears through the enzyme catalase action which rapidly breaks it down into water (Armenteros 2003).

In evaluating the use of H_2O_2 in raw cow's milk preservation, Arefin et al. (2017) found that the addition of 0.14% H_2O_2 to the milk extended the shelf life by 10 h compared to that of the control milk sample. The extension of shelf life followed the ascending order of the added H_2O_2 levels. This is because the LPS prevents acidity from developing by slowing down bacterial growth (Saad et al. 2013). This finding suggests that H_2O_2 stunts the bacterial fermentation of milk sugar resulting in delayed sour flavour development. In addition, there was a gradual reduction in lactic acid concentrations and coagulation in milk samples treated with H_2O_2 . Therefore, 0.14% H_2O_2 can be added to milk to preserve its consumption fitness, however further studies are necessary considering the availability of SCN^- concentration in raw milk and residual concentration of H_2O_2 in milk after processing (pasteurisation etc.) (Arefin et al. 2017).

Action mechanism of LPS. The peroxidation reactions of the SCN^- are complex and depend on several factors, including the concentration and origin of H_2O_2 (Al-Baarri et al. 2011; Bafort et al. 2014). Thom as (1985) proposed a reaction scheme that has still been valid until the present day, indicating the possibility of two different oxidation routes of the SCN^- to OCSN^- (Figure 1).

The major metabolite produced in both reactions is OCSN^- (Al-Baarri et al. 2011). Depending on the reactive process, the reaction may not immediately give rise to OCSN^- ; other intermediate short-lived products may be formed in varying amounts depending on the reaction conditions, including thiocyanogen (SCN^-)₂, cyanogenic thiocyanate (NC-SCN), cyanosulphurous acid (HO_2SCN) and cyanosulphuric acid (HO_3SCN) (Ghiba-udi & Laurenti 2003; Al-Baarri et al. 2011).

Al-Baarri et al. (2019) observed that the LPS had moderate antibacterial effects on *E. coli* in whole milk, skimmed milk, and whey. Lactose reduction from whey remarkably enhanced bactericidal activity. The LPS can effectively act as an antibacterial reagent in reduced-lactose dairy products. It was then presumed that the removal of casein and lactose from the milk enabled the use of LP to reduce

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the bacterial population in fresh milk. It was reported that lactose reduces LP activity by 38% because the sugar molecules interact with the heme cavity of the LP (Al-Baarri et al. 2011). The association of sugar molecules with the heme cavity physically blocked the substrate-binding site, thereby resulting in preventing the interaction of substrate with the heme iron (Singh et al. 2019).

Antibacterial effect. The different groups of microorganisms show a variable degree of sensitivity to the LPS, which may have a bactericidal or bacteriostatic effect depending on factors such as type of microorganism, type of electron donor in membrane proteins, pH, temperature, incubation time and cell density (Al-Baarri et al. 2010; Bafort et al. 2014; Sousa et al. 2014; Almeshdar et al. 2015).

The difference in sensitivity to the LPS can probably be explained by the differences in the cell wall structure and its properties (Sarr et al. 2018). The antimicrobial activity can cause lesions or modifications in the various structures of the microbial cell (cell wall, cytoplasmic membrane, transport system, glycolytic enzymes and nucleic acids), leading to the death or inhibiting the growth of microorganisms (Al-Baarri et al. 2011; Jafary et al. 2013; Bafort et al. 2014).

Gram-negative bacteria are less resistant to the action of the system, having the same bactericidal and bacteriostatic effect, while gram-positive bacteria are more resistant; therefore, the system has inhibitory action only on the growth of these microorganisms (Jafary et al. 2013; Almeshdar et al. 2015).

An important microorganism which causes bovine mastitis is *Staphylococcus aureus*. Although *S. aureus* is readily destroyed during the pasteurising process, the pathogen's enterotoxins may be resistant to pasteurisation and cause food poisoning (Kummel et al. 2016). The LPS is both bactericidal and bacteriostatic for *S. aureus*, *Pseudomonas aeruginosa* and *Escherichia coli* in milk (Shariat et al. 2015).

Listeria monocytogenes is a troublesome pathogen to the dairy industry, so much so that the consumption of milk and contaminated products was related to food listeriosis. *L. monocytogenes* can be found in raw milk, in poorly pasteurised milk and its derivatives (Khan et al. 2016). The risk of listeriosis is amplified by the ability of *L. monocytogenes* to grow at low temperatures and its relative resistance to heat when compared to other bacteria (Khan et al. 2016). The system is bactericidal and bacteriostatic against *L. monocytogenes*. The bactericidal effect of the LPS on *L. monocytogenes* depends on the initial inoculum

concentration, culture medium and storage temperature (Seifu et al. 2004).

The lactoperoxidase system and the dairy industry

The antimicrobial agents of the LPS inhibit milk deterioration, thus preserving the microbiological quality of the milk. The method can be applied to the raw milk of several species, although the system's effectiveness depends on the type of microbiological contamination, the amount of microorganisms and the milk temperature during its use (CAC 1991; Aprodu et al. 2014; Lara-Aguilar & Alcaine 2019). The most commonly recommended industrial application of the LPS in food production is in the dairy industry, more specifically for preserving raw milk during the storage and transport of milk to processing are as (Ndambi et al. 2008; Jooyandeh et al. 2011; Mohamed et al. 2013; Aprodu et al. 2014; Lara-Aguilar & Alcaine 2019). Milk storage time by the LPS at different temperatures is shown in Table 2.

The Codex Alimentarius Commission (CAC) established in 1991 provides guidelines which focus on the application of the LPS in order to avoid milk deterioration during collection and transportation to the processing plant when proper refrigeration is not feasible. Table 3 shows a comparison with regard to milk preservation using only LPS and isolated refrigeration, as well as the association between the two conservation methods.

Since the adoption of these guidelines, a substantial amount of data on the effectiveness of the LPS has been obtained not only from laboratory and field studies but also from the adoption of large-scale use of the system in commercial milk production in some countries such as Cuba, Colombia, Peru, Venezuela, Cameroon, Kenya, Uganda, Pakistan and others (CAC 1991).

Overall, these data confirm the effectiveness of the LPS in preventing the deterioration of raw milk at room

Table 2. Milk storage time by the lactoperoxidase system (LPS) at different temperatures

Temperature (°C)	Time (h)
31–35	4–7
30	7–8
25	11–12
20	16–17
15	24–26
4	120–144

Source: Adapted from FAO/WHO (2005)

Table 3. Comparison between conservation methods using LPS, refrigeration and combination of LPS with refrigeration

	Safety	Microbiological performance	Applicability	Cost benefit
LPS	No public health concerns provided it is used in accordance with the Codex guidelines	1. Mainly bacteriostatic 2. Maintains the initial milk quality for 4–7 h (30 °C to 35 °C) 3. Does not improve milk quality	1. Milk of all species 2. It may interfere with milk fermentation 3. Insignificant adverse effects on the chemical, microbiological and sensory quality	1. Low maintenance cost 2. It can be applied when refrigeration is not a viable option 3. It can increase the availability of milk and dairy products 4. It requires staff training for its use
Refrigeration	No public health concerns	1. Mostly bacteriostatic 2. Maintains the initial milk quality for several days, depending on the temperature of refrigeration and initial microbial quality 3. Does not improve milk quality	1. Milk of all species 2. Insignificant adverse effects on the chemical, microbiological and sensory quality	1. Extends the milk shelf life for several days 2. Does not require addition of chemical compounds 3. High initial maintenance cost
LPS and refrigeration	No public health concerns provided it is used in accordance with the Codex guidelines	1. Mainly bacteriostatic 2. Maintains the initial milk quality for 5–6 days at 4 °C 3. Does not improve milk quality	Milk of all species	1. Increases shelf life of milk and dairy products compared to refrigeration alone 2. Minimum increase in costs

LPS – lactoperoxidase system

Source: Adapted from FAO/WHO (2005)

temperatures within the structure defined by CAC (1991), which is: a) the principles of good hygiene practice in milk production must be respected in order to ensure milk of good microbiological quality; b) the inhibitory effect of the treatment depends on the storage temperature of the milk treated with the LPS. It is important to note that unlike pasteurisation, the LPS does not make milk safer for consumption; it only preserves the initial quality of the product from the place where it is produced until processing.

The antimicrobial compounds in the LPS may interfere with the activity of non-pathogenic starter cultures (ferments, inocula and lactic cultures), thereby affecting the final product quality as LPS reactivation during the manufacturing of fermented products may cause manufacturing problems (Boulares et al. 2011; Atasver et al. 2013).

Sarkar & Misra (1994) established some factors that can affect the use of raw milk treated with the LPS for producing fermented dairy products, including type

of milk used, type of starter cultures used and their inoculation rate, the concentration of SCN^- and H_2O_2 in milk and those used to activate the system, the heating temperature of activated milk, formed antibacterial compounds, incubation time and temperature.

The yield of fresh cheese from cow's milk treated with the LPS was significantly higher than that of cheese made from milk without using the system, as well as its microbiological count, pH and appearance (Lara et al. 1987; Boulares et al. 2011). According to Seifu et al. (2004), the taste of fermented milk and cheese can be improved by LP action, which changes the balance of the microflora.

In relation to other fermented products, yoghurt made from milk treated with the LPS did not present any significant differences in the chemical composition or sensory properties when compared to control yoghurt (Mehanna & Hefnawy 1988). In a study by Ndambi et al. (2008), LPS activation promoted an increase in the shelf life of yoghurts and an increase in the yield

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and sensory quality of cheese. Boulares et al. (2011) also found a favourable effect of treating cow's milk with the LPS on the microbiological quality and cheese yield under limited refrigeration.

Evidence from studies indicates that the LPS has no negative effects on the quality of cheese and fermented products when using a milk which has undergone an appropriate heat treatment after using the system (Ponce et al. 2005).

The LPS use was first intended only for preserving raw milk in places with a tropical climate and when refrigeration was difficult to access; however, as reported its use may include other commercial purposes like in preserved milk using the system to produce several derivatives and thus improving its quality, as shown in Table 4.

It is possible that the LPS has significant action in producing dairy products on an industrial scale, since thermal processes at low temperatures provide greater nutrient retention in foods which are more sensitive to heat – such as creams and dairy drinks – which translates into final product quality, in addition to energy savings. It is also important to consider that the current trend of the 21st century consumer is towards natural foods. These consumers are careful and attentive to preservation methods and health promotion, thus reaffirming the future potential of the LPS in the production of dairy products.

Earnshaw et al. (1989) activated the LPS in cottage cheese by adding the activation components to milk in order to specifically study the changes caused by the genus *Pseudomonas*. The system was effective

in reducing the levels of *Pseudomonas* and *E. coli* *Staphylococcus*, increasing the shelf life and stability of the cheese. The treatment did not affect either the pH or the sensory properties of the cheese.

Abdou et al. (1996) demonstrated that the treatment of cow and buffalo milk with LP and H₂O₂ increased the cheese yield. They also reported that treatment with LP produced cheeses with satisfactory quality which scored better on organoleptic tests. Ramet (2004) found that enriching raw milk with the reagents used for activating the LPS does not modify the sensory properties of the treated milk in relation to the control milk.

CONCLUSION

Lactoperoxidase (LP) has wide applications in the dairy industry, particularly in raw milk preservation in situations where prompt refrigeration is difficult, and especially in developing countries. The lactoperoxidase system (LPS), including the hydrogen peroxide (H₂O₂) and thiocyanate (SCN⁻), is known to extend the shelf life of milk. This may lead to an increase in the amount of milk that could be available for marketing with benefits for both milk producers and consumers.

The natural antimicrobial properties of LPS make it a promising alternative for the industrial conservation and processing of milk, especially when considering the current quality standard demanded by the market. However, the potential of the LPS as a biopreservative is still little technically and scientifically explored, and therefore it implies the need for devel-

Table 4. Effect of the lactoperoxidase system (LPS) on the production processes of dairy products for different species

Products	Species	Effect of the LPS
Milk curd	buffalo	Decreasing diacetyl and acetoin content and proteolytic activity
Fresh cheese	cow	Slow acidification, low moisture retention with satisfactory texture
Gouda cheese	goat	Improving microbiological quality and taste
Manchego cheese	sheep	Preventing excessive proteolysis and softening
Cottage cheese	cow	In sensory tests, taste and different taste from control, increase in cheese yield
Acidophilic milk	cow	Lower content of diacetyl and acetoin and lower proteolytic activity
Mozzarella cheese	buffalo	Lower retention of moisture, slow acidification. Longer time (2 h) to reach the curd stretching stage
Yoghurt	cow buffalo	No difference in chemical composition and sensory qualities No effect on body and texture
Canned cheese	cow and buffalo	Lower processing time and economic use of whey, greater serum expulsion Higher cheese yield and coagulation time, reduced curd tension, increased moisture content and decreased acidity, satisfactory quality and high score

Source: Adapted from Seifu et al. (2005)

oping further studies in this area. In this context, the LPS can be a promising alternative to ensure the safety of milk, considering the current quality standard required by the market.

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