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Natural Treatments for the Control of Foodborne Pathogens

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Abstract

For many years, chemical antimicrobial products have been used to be added in food or drinks. Consumers increasingly prefer to use natural non-toxic compounds as potential antimicrobials to inhibit the growth of foodborne pathogens, avoiding the abuse of chemical preservatives. On the other hand, microorganisms have increased the resistance to these old treatments. So, the development and the implementation of natural food preservation methods to control foodborne pathogens is urgent. The use of natural compounds presents in vegetables with antimicrobial activity have been studied for several authors and their results indicated good potential of natural extracts for application in food products. Lytic Bacteriophages are a possible method to improve the biosecurity in food because it was demonstrated that phages could control some foodborne pathogens with a high specificity and reduced effect on organoleptic properties of foods. And the use of several members of the lactic acid bacteria so as to produce antibacterial substances and preservation of foods.

Keywords: foodborne-pathogens; food; natural compounds; treatments.

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1. INTRODUCTION

Foodborne illness is caused by consuming food contaminated by bacteria and/or their toxins, parasites, viruses, chemicals, or other agents. More than 200 different food-borne illness have been identified [1] and represent a world problem. Unfortunately, every year there is a dramatic increase throughout the world in the number of reported cases of food-borne illness that result from consumption of food contaminated with pathogenic bacteria.

Foodborne diseases occur when a pathogen microorganism is ingested with drink or food and use human as host, some toxigenic pathogens produces a toxin [2].

The frequent foodborne pathogens are *Salmonella*, *Escherichia coli*, *Staphylococcus aureus, Listeria monocytogenes Yersinia enterocolitica Clostridium botulinum, C. perfringens, Bacillus cereus*, *Bacillus subtilus,* among others. Their effects could be eliminated by preventing contamination or by the destruction of microorganism in infected food.

2. FOODBORNE PATHOGENS

Escherichia coli is a natural intestinal inhabitant of humans and warm-blooded animals. Animal fecal matter is main source of pathogenic bacteria on meat products [3] where this specie provide absolute proof of fecal contaminations. *E. coli* can produce diarrhea, urinary tract infections, inflammations and peritonitis in immune-suppressed patients as children and elderly people [4]. Some strains, such as enterohemorrhagic *E. coli* produces foodborne disease and the infection occurs by received food contaminants like undercooked ground beef, unpasteurized milk, or contaminated water.

Listeria monocytogenes is found in soil, water, dairy products, and in raw and undercooked meat, poultry and seafood. It has become a major concern to the food-processing industry and is an alert for health authorities in recent time period. *Listeria monocytogenes* assumed public health significance due to its hazardous presence in foods. Despite the efforts to eradicate the organism from foods, *L. monocytogenes* contamination continues to occur. This organism may cause meningitis, sepsis or abortion, but in practice only pregnant women and people with immune defects are in danger of infection [5].

Salmonella bacteria can cause salmonellosis that is a gastrointestinal illness. Salmonellosis is a disease still searching for preventive techniques to avoid contamination. *Salmonella* can be spread by contamination with hands or the surfaces and tools they use for food preparation, but the main transmission route is by microorganisms' ingestion in milk, meat, poultry or eggs derived from infected animals. Salmonellosis produces diarrhea, high fever, headaches, and in some cases may become fatal.

S. Typhimurium causes gastroenteritis in mammals, humans which could provoke bloody diarrhea. Recently, some authors demonstrated that salmonellosis during pregnancy produces a fetal loss and preterm birth in humans and suggested that these complications could be associated with alterations in placental structure [6]. *Salmonella enterica* and *E. coli* are main foodborne pathogens.

Also *Staphylococcus aureus* in food is hazardous in public health hazard because produces enterotoxin and the subsequents.

So, the use of food preservatives to control foodborne pathogens is very important for human health.

3. FOOD PRESERVATIVES

The exploration of natural antimicrobials for food preservation receives increased attention due to a growing microbial resistance towards conventional preservatives, added to consumer awareness of natural food products [7]. For many years, synthetic or semi-synthetic antimicrobials have been used, but microorganisms have increased the resistance to these treatments. So, the implementation of new food preservation methods to control foodborne pathogens is urgent.

3.1. Natural compounds

Consumers increasingly prefer to use natural extracts as potential antimicrobials to inhibit the growth of pathogenic bacteria, avoiding the abuse of chemical preservatives and sterilization technologies that are known to impair the nutrition quality of food [8]. Application of naturally occurring antimicrobial compounds and bio-preservatives is also gaining popularity for fruit juice processing as a replacement for thermal pasteurization [9].

Natural extracts from plants are used for the control of pathogenic microorganisms. The antimicrobial activity of vegetal extracts is attributed to the presence of some secondary metabolites, such as phenolic compounds. Some problem with the application of these extracts in food as food preservatives is their influence in the organoleptic properties of the food.

Vallejo *et al*. [10] reported the phenolic compound profile of Argentine strawberry cultivars and the antibacterial activity of low molecular phenolic fraction (LMPF) against *Salmonella* Typhimurium and *Listeria monocytogenes* as well as individual phenolic compounds present in the extracts, such as quercetin, kaempferol and chlorogenic, ρ-coumaric and ellagic acid. The authors reported that the possible mechanism of action of LMPFs against *L. monocytogenes* would be related to the disruption of cytoplasmic membrane integrity (Figure 1), and that probably the presence of quercetin and kaempferol in these LMPFs would be the main cause of this effect. On the contrary, the antibacterial mechanism of action of the phenolic extracts of cultivars *Camarosa* and *Albion* on *S.* Typhimurium would be related to an inhibition at the level of the electron transport chain, avoiding the consumption of oxygen by inhibiting the activity of NADH oxidase or other related enzymes.

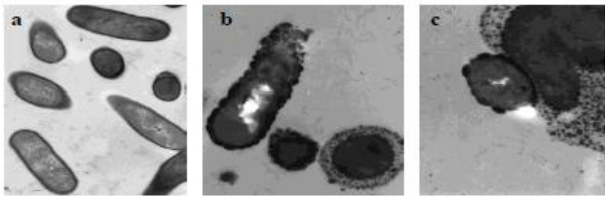

Figure 1. Electron microscopy analysis of effect of LMPFs on *Listeria monocytogenes* with 12800x in control buffer (a) and in buffer added with LPMPs from *Albion* (b) and *Camarosa* (c) strawberry after 3 h of contact. Source: Vallejo *et al.* (2020).

Other authors explored the use of cinnamon as natural antimicrobial agent on *E. coli* and *St. aureus* [11] and their results indicated good potential of cinnamon for application in food products.

Rodríguez-Vaquero *et. al* [12] demonstrated the antioxidant and antihypertensive activities of phenolic compounds in Argentinean red wines and their relation with the phenolic content, as well as their antibacterial activity against *E. coli*, *St. aureus*, *Ps. aeruginosa*. *E.coli* and *L. monocytogenes.* The authors demonstrated that polyphenols from wines inhibited the biofilm formation on pathogenic bacteria, see Figure 2.

Figure 2. Effect of phenolic compounds from malbec (□), merlot (▢) and cabernet savignon (■) wine varieties in biofilm formation. Source; Rodríguez-Vaquero *et al.* (2020)

In other investigation, the antibacterial activity of phenolic or fatty fraction from wastes from winery industry were demonstrated against *Pseudomonas* sp., *Klebsiella* sp., *Salmonella* sp., y *E. coli* y sobre *Pseudomonas* PA14, *Pseudomonas* PA01 [13] (Garzia *et al.*, 2019).

3.2 Bacteriophage for biocontrol

Developing novel antimicrobials capable of controlling bacterial pathogens is essential and the use of bacteriophages for the control of food-borne pathogens is increasingly gaining acceptance. Bacteriophages are viruses that infect bacteria, replicate within the host and those which are lytic, cause cell lysis. Phages lytic to foodborne pathogens are potent weapons against some enemies (*Salmonella enterica, E. coli, Listeria monocytogenes* or *Shigella* spp) for food industry. Their specificity, effective mode of action [14], reduced effect on organoleptic properties of foods [15].

Lytic Bacteriophages are a possible method to improve the biosecurity in food because they replicate only on the targeted bacterium. However, antibiotics in animals have been widely used as prophylaxis and treatment of infectious diseases, which provides the selective pressure on foodborne pathogens. Nowadays, the control of resistant pathogens has been improved with the development of bacteriophage based approaches such as single phage therapy, synergistic approach or phage cocktail [16].

The use of bacteriophages against *Salmonella enteritidis* as a prevention method was investigated by Garcia *et al.* [17]. Two tests with three concentrations of bacteriophages were conducted against two strains of *Salmonella* Enteritidis. Results demonstrated that the use of bacteriophages reduced *Salmonella enteritidis* isolates in faeces at 24 hours after the application, so it could be considered as a prevention tool.

A lot of of bacteriophages isolated and used in different food matrices controlling Gram-positive and Gram-negative bacterial pathogens whie their effect was food-type and phage-concentration dependent. In food, bacteriophage DT1 and DT6 produce a complete reduction of *E. coli* O157:H7 in milk [18], whereas bacteriophage cocktail sprayed on spinach blades resulted in a reduction of the number of viable cells [19]. Hence bacteriophages are more effective in liquid foods than solid ones. [20].

Walker *et al.*, [21] investigated the application of lytic bacteriophage on chicken breast; the authors observed a significant reduction of *S*. Typhimurium counts. And a significant reduction of *S*. Typhimurium was observed when 5% of phage and 20 mg/mL of lactobionic acid, were combined used on chicken breast. The highest log10 reduction was shown by 5% phage, which reduced the pathogen by 2.17 log10 CFU/cm^2 when compared with control.

4. CONCLUSIONS FOR ANTIMICROBIAL PRODUCTS - LAB

Except the above useful antimicrobial products for stakeholders should be based on lactic acid bacteria, LAB, for environmental health and public health protection. Several members of LAB are known to produce antibacterial substances and LAB are applied for centuries in the preparation and preservation of foods of meat, milk, and vegetable origin and have a recognition as safe (GRAS). A substance or microorganism may be GRAS only if its general recognition of safety according to views of experts qualified to evaluating the substance. Starter cultures for cheese and sour milk production were introduced in 1890, while fermented food has been used by man for more than 5,000 years [22].

Recently, some authors reported potential applicability of LAB isolates as green bio protective agents against pathogenic microorganisms in the seafood industry [23]. Rodríguez-Vaquero *et al.* [24] isolated and identified seven homofermentative LAB (*Lactobacillus plantarum* SB1, SB2, SB5, SB6, SB12, JB1 and JB2). All of LAB supernantants were effective reducing viable cells as well as biofilm formation of the five pathogenic bacteria, such as *E. coli*, *S. aureus* and *Enterococcus faecalis*.

With respect to the number of viable cells, the highest reduction of *E. coli* and *Enterococcus faecalis* were observed with *L. plantarum* SB1 supernatants, whereas *L. plantarum* SB12, SB5, and SB6, were the most effective against *E. coli ATCC* 25922, *E. coli ATCC* 35218 and *Staphylococcus aureus*. All LAB supernatant produce inhibition on bacterial biofilm formation.

LAB isolated from fermented fish and chicken were able to produce active compounds that inhibit biofilm development and cell proliferation of various foodborne pathogens, such as *Bacillus cereus* ATCC 11778, *Escherichia coli* ATCC 8739, and *Salmonella enterica subsp. enterica serovar* Typhimurium ATCC 13311. So, the authors suggested that the antimicrobial activity of the isolated LAB could also be considered for use in the food processing industry for sanitizing purposes [25]. All the above should be taken into account for stakeholders as well as vocational training education for sustainability and public health protection.

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