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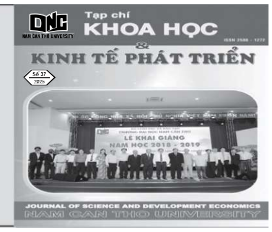

The role of lactic acid bacteria in food processing and improving bioactive compounds in the human body

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ABSTRACT

Clinical studies have shown that selecting lactic acid-fermented products helped to enhance resistance to intestinal pathogens, stimulate the immune system, and help maintain a balanced intestinal microflora. Some advantages of traditional fermentation were labor-intensive, integrated with rural life, and was a familiar fermentation technology. In addition, lactic acid fermentation was less expensive, and the value of fermented foods was enhanced in trade. From these perspectives, research on new fermentation technologies should be given more attention to the social and economic factors in developing countries.

1. INTRODUCTION

Lactic acid bacteria (LAB) are a group of pleomorphic bacteria characterized by their ability to produce a common metabolite (lactic acid) from sugars. LAB currently associated with food include species from the genera Carnobacterium, Enterococcus, Lactobacillus, Lactococcus, Leuconostoc, Oenococcus, Pediococcus, Streptococcus, Tetragenococcus, Vagococcus, and Weissella. Their proteolytic and lipolytic activities are often recorded as minor and contribute little to the flavor of fermented foods. The main activity of this group of bacteria is to utilize carbohydrates for fermentation to produce lactic acid. Besides lactic acid production, LAB can produce aromatic compounds such as acetate, diacetyl, acetoin, and acetaldehyde, which are important for the flavor of some dairy products.

Lactic acid fermentation is the primary fermentation reaction in most fermented dairy, meat, and vegetable products. Lactic acid fermentation is carried out under anaerobic conditions by microorganisms belonging to the lactic aid bacteria group. In homolactic fermentation, the pathway followed is the Embden-Meyerhof-Parnas pathway, and only lactic acid is the end product. In heterolactic fermentation, the pathway followed is the pentose phosphate pathway (phosphogluconate pathway), and the end products are lactate, ethanol, and finally acetate. Based on the types of lactic acid fermentation performed, LAB types are divided into: (1) obligate homofermentative, (2) obligate heterofermentative, (3) facultative homofermetatve

Obligate homofermentative species cannot degrade fructose-1,6-bisphosphate into dihydroxyacetone-phosphate and glyceraldehyde-3-phosphate. The enzyme responsible for catalyzing this conversion (fructose-1,6-bisphosphate aldolase (EC 4.1.2.13)) is absent or suppressed (Moat, 1985).

In facultative homofermentative species, the subsequent fermentation type depends on the abundance of fermentable carbohydrates in the medium. These microorganisms are homofermentative when carbohydrates (lactose or glucose) are abundant in the culture medium, and they become heterofermentative when these carbohydrates are present in limited concentrations. The cell's choice between the two fermentation mechanisms depends on the concentration of fructose-1,6-bisphosphate. Fructose-1,6-bisphosphate activates the activity of lactate dehydrogenase in LAB and can inhibit the NADP-dependent glucose-6-phosphate dehydrogenase enzyme. Therefore, at low carbohydrate concentrations and low fructose-1,6-bisphosphate concentrations, the heterofermentative pathway can operate in these homofermentative species.

For heterofermentative LAB, ethanol is produced via the pentose phosphate pathway from the reduction of acetyl-phosphate. This pathway also results in the production of insignificant amounts of CO_2. In contrast to what occurs in plants or animals, LAB can produce not only D(+)-lactic acid but also L(-)-lactic acid, or both isomers. This depends on the type of lactate dehydrogenase (LDH) present: L(+)-LDH, D(-)-LDH, or both. Lactic acid in lactic-fermented foods plays a very important and diverse role, serving as a pH regulator, preservative, flavor enhancer, and flavor compound.

2. RESEARCH METHODS

This study was conducted using a qualitative approach through the synthesis of relevant documents.

3. RESULTS AND DISCUSSION

3.1 The role of LAB in food color changes

Olives are harvested at the green or black stage, preserved, size-sorted, and then placed under anaerobic, or in some cases aerobic, conditions in brine with a salt concentration ranging from 6% to 8% NaCl, and left to natural fermentation for several months (Romero et al., 2004). Osmotic exchange leads to the leaching of substrates such as carbohydrates (mainly glucose, as well as fructose, mannitol, and sucrose) and organic acids (malic, citric, and acetic). As a result, the aqueous solution (brine) becomes a good environment for microbial growth. In the processing of Spanish-style green olives, the bitterness is completely removed by hydrolysis with NaOH solution over several days. During this period, water-soluble oleuropein and sugars are eliminated and converted (Piga and Agabbio, 2003). Processing ripe olives (by dark covering in an alkaline environment) involves successive treatments of olives with NaOH solution (alkaline solution) for three consecutive days, and in the period between alkaline treatments, the olives are suspended in water or diluted brine through which air bubbles are passed. Finally, gluconate or lactate solutions containing pigment are added to adjust the color (Brenes-Balbuena et al., 1992).

Throughout the fermentation process, the use of a lactic bacterial system in NaCl solution aimed at reducing pH is the primary choice (increasing from 1% of the total bacterial population in fresh brine to 80% after a few days). Indigenous lactic acid bacteria (LAB) change spontaneously throughout the natural fermentation process, and at the end of the process, Lactobacillus species participate, mainly *Lactobacillus plantarum* (Rodriguez et al., 2009) at a rate of 39.9% of the total (Sanchez-Gomez et al., 2006), although other LAB species such as *Lactobacillus pentosus* and *Leuconostoc mesenteroides*, among many others, have also been isolated (Rodriguez et al., 2009). During the first fermentation stage, gram-negative rods are the most characteristic microorganisms, and their mechanism leads to the production of CO2, hydrogen, acetic acid, lactic acid, ethyl alcohol, etc., as end products. During the second stage, as a result of the pH drop (pH decreasing to 4.5), the vigorous growth of Lactobacilli begins; they produce only lactic acid as the end product of glucose fermentation. During the third stage, when the pH reaches 4.0 or lower, acid formation stops (Minguez-Mosquera et al., 1989), and when sugars are depleted, the fermentation period can be considered ended and the preservation time begins.

After fermentation, olives are stored in similar brine until curing is achieved, before packaging and commercialization. The addition of preservatives or heat pasteurization is often used in packaging fermented vegetables to ensure microbiological stability during storage (Sanchez-Gómez et al., 2006).

3.2 The role of LAB in removing harmful components present in food raw materials

Lactic acid fermentation is carried out by various bacteria, most frequently lactic acid bacteria such as *Lactobacillus acidophilus, Streptococcus thermophilus, Lactobacillus plantarum, Lactococcus lactis, Leuconostoc mesenteroides*, etc. Foods produced by lactic acid bacteria include yogurt, cheese, and pickled vegetables. The classification of LAB was initiated in 1919 by Orla-Jensen. LAB comprise a diverse group of gram-positive, non-spore-forming, non-motile rods and cocci. LAB are chemoorganotrophic and only grow in complex media; carbohydrates and alcohol are used as energy sources to form lactic acid. LAB can degrade hexose into lactate (via the homofermentative pathway) or lactate and various byproducts such as acetate, ethanol, CO_2, formate, or succinate (via the heterofermentative pathway).

LAB are abbreviated as probiotics in scientific literature (Lilley and Stillwell, 1965) [20]. Fuller (1989) described probiotics as "live microbial feed supplements which beneficially affect the host animal by improving its intestinal microbial balance". According to Schrezenmeir and De Vrese (2001), probiotics are viable microbial food supplements that beneficially affect host health. LAB can be effective in preventing digestive disorders and restoring health caused by digestive diseases of various origins (Marteau et al., 2001). Many bacterial strains are classified and inhabit different environments, producing antimicrobial substances against other bacteria.

LAB are of great interest because they promote enhanced health in animals and humans (Gorbach, 1990; 2000).

Organic acids are important products of LAB fermentation. The concentration and type of organic acids produced during fermentation depend on the type of microorganism involved. The antimicrobial effect of organic acids lies in their pH-reducing characteristic as well as the undissociated form of the molecules (Gould, 1991; Podolak et al., 1996). Acids are generally recognized to exert their antimicrobial effects by interfering with the maintenance of cell membrane potential, inhibiting transport activity, reducing intracellular pH, and inhibiting a range of metabolic functions (Doores, 1993). Organic acids have a broad spectrum of activity and inhibit both gram-positive and gram-negative bacteria as well as yeasts and molds (Blom and Mortvedt, 1991).

Food fermentation is one of the oldest forms of biological preservation practiced by humankind. The fermentation process involves the breakdown of complex organic substances into simpler ones. The fermentation process involves the oxidation of carbohydrates to produce a range of products, mainly organic acids, alcohol, and CO_2 (Ray and Daeschel, 1992). Fermentation involving the production of ethanol generally makes food and beverages safe (Steinkraus, 1979).

Protection of food from spoilage and pathogenic microorganisms by LAB is achieved through the production of organic acids, H_2O_2, and diacetyl (Messens and De Vuyst, 2002) as well as antifungal compounds such as fatty acids (Corsetti et al., 1998) or phenyllactic acid (Lavermicocca et al., 2000) and/or bacteriocins (De Vuyst and Vandamme, 1994). LAB play an important role in fermented foods, as the resulting products are characterized by food safety, enhanced shelf life and stability, and attractive sensory properties. Lactic acid inhibits many types of pathogenic bacteria, and the undissociated form of the acid is considered the active component (Robinson and Samona, 1992). The amount of undissociated lactic acid depends on both the lactic acid concentration and the pH. Kingamkono et al. (1996) added several intestinal pathogens to sorghum-based cereal porridge preparations and inoculated them with a lactic acid starter culture. During fermentation, Campylobacter was not detected after 6 hours, while Salmonella, Shigella, and Staphylococcus were not detected after 12 hours. After 16 hours, no viable Bacillus strains were found, and enterotoxigenic *E. coli* (ETEC) was completely inhibited after 24 hours. On the other hand, in porridge preparations without a lactic acid starter culture, all intestinal pathogens increased in number during incubation at 32 °C except for Campylobacter (decreasing after 12 hours).

In traditional fermented preparations, bacteria are used to prepare and preserve products (Achi, 1992). Fermented foods have many advantages such as enhancing nutritional value and protection against pathogenic bacteria (Gadaga et al., 2004). According to Adams (1990), fermentation can contribute to enhancing food stability, safety, nutritional value, and acceptability. LAB are added to salad and olive mixtures to prevent the growth of pathogenic microorganisms. A certain amount of LAB is used in the biological control of aflatoxin. Karunaratne et al. (1990) demonstrated the suppression of aflatoxin production by

Aspergillus flavus in the presence of *Lactobacillus acidophilus, Lactobacillus bulgaricus*, and *Lactobacillus plantarum.*

Food processed under unhygienic conditions and frequently contaminated with pathogenic microorganisms plays a key role in child mortality through a combination of diarrhea, nutrient malabsorption, and malnutrition. Salmonella, Campylobacter, Shigella, Vibrio, Yersinia, and Escherichia are the most common microorganisms associated with bacterial diarrhea. Enterotoxigenic bacteria including Pseudomonas, Enterobacter, Klebsiella, Serratia, Proteus, Providencia, Aeromonas, Achromobacter, and Flavobacterium have been reported by Nout et al. (1989). Adams (1990) suggests that LAB inhibit many other microorganisms when co-cultured, and this fact is the basis for extending shelf life and improving the microbial safety of lactic-fermented foods. Fermentation by LAB is one of the oldest forms of biological preservation practiced by humankind. An important attribute of LAB is their ability to produce antimicrobial compounds such as bacteriocins (antibacterial substances that are peptides synthesized at the ribosome by both gram-negative and gram-positive bacteria to inhibit other competing bacteria). Fermentation is a process dependent on the biological activity of microorganisms in creating a range of mechanisms that can prevent the growth and survival of unwanted microorganisms in food (Klaenhammer, 1993; Soomro et al., 2002).

Vegetable and vegetable/fish/shrimp mixtures are preserved worldwide by lactic acid fermentation (Steinkraus, 1983). Classic lactic acid fermentation of vegetables is sauerkraut (Pederson, 1979). Maize fermentation can increase the total soluble solids content and non-protein nitrogen and slightly increase protein content (Yousif and El Tinay, 2000). Lactic acid fermentation generally improves the nutritional value and digestibility of cereals. Cereals are limited in essential amino acids such as threonine, lysine, and tryptophan, thus making their protein quality inferior to that of meat and animal milk (Chavan and Kadam, 1989). Their protein digestibility is lower than that of animal meat, partly due to the presence of phytic acid, tannins, and polyphenols bound to proteins, making them difficult to digest (Oyewole, 1997). Lactic acid fermentation of various cereals, such as maize and sorghum, has been found to be effective in reducing the amount of phytic acid and tannins and enhancing protein availability (Chavan et al., 1988; Lorri and Svanberg, 1993). Increased amounts of riboflavin, thiamine, niacin, and lysine due to the action of LAB in fermented cereal blends have also been reported (Hamad and Fields, 1979; Sanni et al., 1999). The beneficial role of probiotics is to aid in food breakdown while also producing many essential vitamins for the body and breaking down and destroying some toxic chemicals (which can enter the body with food).

3.3 The role of LAB in improving bioactive compounds in the human body

Some Lactobacillus strains are capable of producing or enhancing bioactive compounds in fermented foods, such as *L. acidophilus, L. delbrueckii, L. helveticus, L. lactis, L. plantarum, L. rhamnosus*, etc. The prominent proteolytic activity of LAB is caused by cell-bound proteinases and several intracellular peptidases, including aminopeptidases, dipeptidases, endopeptidases, and tripeptidases. Some bioactive peptides, for example, have antioxidant, antimutagenic, and immunomodulatory properties. The release of bioactive peptides depends heavily on the selection of bacterial strains that ensure a balance between product integrity and the appropriate level of proteolytic activity necessary to release these bioactive peptides. Folate can be produced by certain microorganisms in certain foods. With a few exceptions (*L. acidophilus, L. plantarum*), Lactobacilli are known not to synthesize folate but rather to consume it.

4. CONCLUSION

Fermentation can protect food by removing harmful components. LAB fermentation has long been particularly supported by organizations in the production of safe and nutritious food that can also elicit positive effects on human health. There is increasing evidence that the presence of LAB in fermented products is indeed very beneficial for health. This demonstrates the potential for the future development of lactic acid fermented foods.

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