Abstract

Worldwide, there is an increasing consumer demand for healthy and safe meat products. To meet that growing demand, attention has been directed to the use of fermented meat products as food carrier for probiotics. Probiotic meat products are a fairly new and not very well recognized in food market. Identifying a single or a mixture of probiotic bacteria that inhibit the growth of spoilage and pathogenic bacteria is of growing interest for research to improve the shelf life and safety of the meat products.

Research results indicate that fermented meat products such as sausage can be manufactured using probiotic starter cultures. Some studies describe the behavior of previously selected probiotic strains for their use in fermented sausages production or the potential probiotic use of some selected strains present in commercial meat starter cultures. Many scientists have proposed the use of probiotic lactic acid bacteria (LAB) isolated from fermented sausages which are harbors high numbers of LAB. According to studies, fermented sausages are dominated by LAB, represented mainly by Lactobacillus sakei, L. curvatus, L. plantarum and by coagulase-negative cocci. In the technological process of probiotic meat products, research results revealed that it is important to enhance the desired bacteria count while inhibit spoilage and pathogenic bacteria. It is demonstrated that probiotic bacteria also contribute to the decrease cholesterol level by deconjugation of bile salts and facilitate absorption of calcium, iron, and zinc. Therefore, previous studies emphasized that the choice of appropriate microorganisms is important to create meat products with beneficial health effects. Even though several approaches have been attributed but most of study results are preliminary to be able to draw solid conclusion about the effect of probiotic fermented meats on human health.

This review study presents the potential applications of probiotics in fermented meat products by focusing on the technological challenges, the functional effects of probiotics in meat system and the researches that address the addition of probiotics in fermented meat products.

Key words: Lactic acid bacteria, Probiotics, Meat products.

1. Introduction

Food, health, safety and quality have been given an increased focus. The increasing consumer demand for good tasting, healthy, safe and environmentally friendly produced food has put demand on producers. Optimized product shelf life is no longer the only criterion to be fulfilled in order to be successful in the market. It is no longer enough for food to contain bioactive ingredients in quantities enough for the food to survive processing and storage, but the food must also function as a vehicle for delivery of these components to humans during consumption in quantities enough to have the desired function. Worldwide, meat is by far the most consumed food product of animal origin. Several factors contribute to the popularity of meat products, of which sensory, dietary and economic factors are the most significant. Meat by its research and studies has been to identify a single or a mixture of starter culture or probiotic bacteria that inhibit the growth of spoil-
age and pathogen bacteria and as a consequence, the shelf life of the meat products can be extended and healthier meat products can be developed.

Nowadays, there is a considerable interest towards probiotics for a variety of medical conditions, and millions of people around the world consume probiotics daily to maintain well-being [1]. Such meat products would increase the quality and safety of the meat products and improve the economic benefits of producers and health benefits of consumer.

2. Applications of lactic acid bacteria and probiotics in fermented meat products

2.1 Importance of starter cultures in fermented meat products

Preservation of meat products by fermentation has been used for hundreds of years. Starter cultures have a very important role in production of high quality meat products because of their effect on pH, the desired flavor development, as well as providing stability and safety. Therefore, it is important to determine which starter culture or combinations should be used to manufacture safe and high quality meat products for consumers.

For centuries, lactic acid bacteria (LAB) have been used for the preservation of food for human consumption. LAB are a large group of fermentative, anaerobe facultative, aerotolerant microorganisms which are usually present in the gut of humans and other animals, raw vegetables, meat and meat products, and cereals [2]. Functional meat products produced by lactic acid bacteria having probiotic properties and other probiotic bacteria sources are getting attention in the meat industry. It was reported that starter culture combinations (S. xylosus + P. pentosaceus, L. plantarum + S. carnosus, S. carnosus + L. pentosus, S. xylosus + P. pentosaceus, P. acidilactici, S. carnosus + P. pentosaceus and S. xylosus + L. alimentarius) improve quality characteristics and have positive effects on chemical and microbiological characteristics of fermented meat products [3].

As for pathogens of concerns, Ceylan and Fung [4] reported that inoculated Y. enterocolitica (5 log cfu/g) can be eliminated completely in fermented meat products by using starter cultures (L. sake + P. acidilactici), Kaya and Gökalp [5] indicated that starter cultures (L. plantarum + S. carnosus) inhibit growth of L. monocytogenes (4 log cfu/g) in fermented meat products. The use of P. pentosaceus, P. acidilactici, bacteriocin negative L. sakei or L. plantarum as a starter culture has an inhibitory effect on growth of L. monocytogenes (4 log cfu/g) in fermented sausage [6]. Another study indicated that a significant inhibitory effect of the lactic acid bacteria strains (P. acidilactici 413, 419 and 446, P. pentosaceus 416) on the L. monocytogenes can be achieved due to the presence of bacteriocin-like metabolites. According to this study, P. acidilactici 413, 419 and 446, and P. pentosaceus 416 strains have the best potential for use as fermented sausage starter cultures since these strains are very adaptable to the environment found in fermented meat products [7]. Antibacterial activities of lactobacilli strains (L. sake, L. curvatus, L. plantarum) against to L. monocytogenes and S. aureus were also reported [8]. On the other hand, the effect of starter cultures (L. plantarum + S. carnosus) and nitrite (100, 150 and 200 ppm) on E. coli O157:H7 was reported as insignificant [9].

Study on the viability of E. coli O157: H7 during manufacturing and storage of sausage indicated that the greater reduction (6.4 log) in pathogen numbers can be achieved in fermented sausage prepared with a starter culture after 21 days storage at 25 °C than that achieved by storage at cooler temperatures (4 and 15 °C). However, a 2.6-log reduction can also be obtained after 21 days at 25 °C in sausage prepared without a starter culture. The authors suggested that sausage may allow the survival of E. coli O157:H7 in the absence of controlled fermentation, post-fermentation cooking, and/or an ambient-storage processing step [10, 11]. On the other hand, it was reported that in sausage manufactured with L. plantarum + S. carnosus as a starter culture, E. coli O157:H7 (2 and 6 log cfu/g) cannot survive [12]. Cosansu and Ayhan [13] indicated that E. coli O157:H7 survives for a longer period of time in vacuum-packaged sausage samples than non-vacuum samples. Porto-Fett et al. [14] concluded that sausage does not provide a favorable environment for outgrowth/survival of L. monocytogenes, S. typhimurium, or E. coli O157:H7. Another study [15] shows that Campylobacter jejuni (5 log cfu/g) in sausage can be inactivated readily on day four of ripening of sausage with pH of 5.25.

2.2 Effects of probiotics on quality parameters of fermented meat products

Probiotics are live microorganisms that provide a beneficial effect on the host by improving the microbial balance of the intestinal tract [16]. Probiotic strains must be derived from human or animal and recognized as GRAS [17]. The criteria’s for the selection of probiotics include the lack of pathogenicity, the tolerance to gastrointestinal conditions (acid and bile), the ability to adhere to gastrointestinal mucosa and the competitive exclusion of pathogens [18].

Probiotic bacteria should be able to survive during the food production process and passing through human digestive system in order to show their beneficial effects. Therefore, the determination of probiotic bacteria behaviors under conditions similar to the human digestive system has a great importance [19, 20]. On the other hand, probiotics in fermented meat products can
be protected by fat and meat particles against human gastrointestinal conditions. It is also believed that some of the meat and fat particles may be a source of energy for probiotic bacteria in human digestive tract [21]. In addition, meat provides good conditions for protection of probiotic lactic acid bacteria against acidic conditions of human digestive system and the inhibitory effect of bile salts due to its buffering capacity [22]. Even though raw fermented meat products such as sausages contain high numbers of lactic acid bacteria which, however, are not regarded as probiotics.

Probiotics are mainly the strains from species of *Bifidobacterium* and *Lactobacillus*. Other than these, some species of *Lactococcus*, *Enterococcus*, *Saccharomyces* and *Propionibacterium* are considered as probiotics due to their ability to promote health in the host [23]. Recently, attention has been directed to the use of fermented meat products as food carrier for probiotics. Identifying a single or a mixture of probiotic bacteria that inhibit the growth of spoilage and pathogenic bacteria is of growing interest for research to improve the shelf life and safety of the meat products. Therefore, it is important to search for probiotics for possible applications in fermented meat products. *Lactobacilli* are of the most importance in meat fermentation because of their ability to provide, in the presence of fermentable sugars, rapid and effective acidification thus preserving the sausages from the development of spoilage and pathogenic bacteria. This is why they are often used as starters in dry fermented sausage production. Combining probiotic potential and technological performances of *Lactobacillus* strains would lead to interesting probiotic starters for use in novel dry fermented sausages.

In fermented meat products, several studies have demonstrated the feasibility of using probiotic *Lactobacillus* represented mainly by *Lactobacillus sakei*, *Lactobacillus curvatus*, and *Lactobacillus plantarum* and by coagulase-negative cocci. Pennacchia et al., [24] reported the use of *Lactobacillus plantarum* and *Lactobacillus paracasei* as probiotics in meat products. The use of probiotics (*L. acidophilus* and *B. lactis*) in fermented sausage manufacture reduce lipid oxidation, total aerobic bacteria, lactic acid bacteria and micrococci/staphylococcus counts in fermented sausage. Therefore, *B. lactis* and *L. acidophilus* can be used together with starter cultures in fermented meat products manufacture as probiotic sources [25]. Erkkilä [26] reported that probiotic and bioprotective *L. rhamnosus* strains GG, LC-705 and E-97800 can produce high quality dry sausage with decreased risk for *L. monocyctogenes* or *E. coli* O157:H7. Erkkilä et al., [27, 28] reported that the use of potential probiotic cultures (*L. rhamnosus* GG, *L. rhamnosus* E-97800 and *L. plantarum* E-98098) had no adverse effect on sensory and technological properties of fermented sausages. Pidcock et al., [29] indicated that the use of *L. paracasei* L26 and *Bifidobacterium lactis* B94 with traditional culture had also no adverse effects on sensory properties of fermented meat products. Sameshi et al., [30] reported that probiotic *L. rhamnosus* FERM P-15120 and *L. paracasei* subsp. *paracasei* FERM P-15121 inhibited the growth of *S. aureus* and its enterotoxin production in fermented sausages during fermentation period. Holko et al., [31] suggested that probiotic strains of *Lactobacillus acidophilus* CCDM 476 and *Bifidobacterium animalis* 241a can be used in fermented sausage manufacture instead of the traditional starter cultures to produce probiotic sausages with similar quality parameters with traditional fermented sausage. Sidira et al., [32] indicated that using probiotic *Lactobacillus casei* ATCC 393 significantly reduced the number of *Pseudomonas*, *Enterobacteriaceae* and *Staphylococci* in fermented sausages during ripening period.

### 2.3 Challenges surrounding the use of probiotics for the manufacture of fermented meat products

The viability of the probiotic cultures in fermented meat products is significantly affected by several factors such as: pH, hydrogen peroxide, organic acid concentration, the presence of other microorganisms, temperature, oxygen content, moisture content, salt, sugar and additives [33]. Fermented sausages have a negative impact on the viability of probiotic bacteria because of their high acidity conditions compared with conditions in non-fermented meat products.

One of the most important factor affecting the growth and stability of probiotic bacteria in fermented meat products is the pH. For instance, probiotic *L. acidophilus* and *Bifidobacteria* need the optimum pH range between 5.5 - 6.0 and 6.0 - 7.0 respectively [34]. The probiotic bacteria need to maintain their viability towards the adverse conditions generated in fermented meat products during the fermentation. These conditions are low pH (< 5.0), high salt content (2 - 3%), high nitrite content (around 120 - 156 ppm) and low water activity (< 0.85).

The probiotic cultures should also be capable of growing fast during the fermentation, be easily cultivated on an industrial scale, resist to freezing and lyophilization processes, provide longer shelf life to the product as well as contribute to the sensory quality of the final product [27, 35]. Rivera-Espinoza and Gallardo-Navarro [36] encapsulated *Bifidobacterium longum* and *Lactobacillus reuteri* in alginate to increase the survival of these probiotics in fermented meat. Poulin, Caillard, and Subirade [37] created succinylated β-lactoglobulin tablet to protect *B. longum* strain and proved its protective effect in-vivo and in-vitro. Heidebach, Först and Kulozik [38], reported that higher viability of *Lactobacillus* F19 encapsulated with casein during freeze storage compared to *Bifidobacterium* Bb12. Further-
more, the same authors [39] microencapsulated these two strains with rennet-induced gelation of milk, and obtained improved survival rates. Some researchers suggested to only use probiotic species having 4 h tolerance for pH 2.5 in the culture medium [40, 41].

3. Conclusions

- Significant data have been accumulated on lactic acid bacteria and other probiotics and their beneficial health effects. Furthermore, more insights and key findings on the impact of processing and storage on probiotic viability and stability have been obtained.

- A variety of microorganisms, typically food grade lactic acid bacteria, have been evaluated for their probiotic potential and are applied as adjunct cultures in various types of meat products. However, further studies are needed to determine if preventive probiotic strategies are safe with regard to development of probiotic infections.

- Cooperation amongst food technologists, medical and nutrition scientists, and anticipation of future consumer demands are crucial for future success to meet consumer demands about probiotic meat products.

- Research results suggested that the use of probiotic lactic acid bacteria and other probiotic cultures may be a useful and effective strategy to prevent or reduce pathogens in the meat products, improve meat product shelf life and consumer health. Such an approach can yield sufficient credibility needed to persuade producers, consumers, and policy makers about the value of probiotic fermented meat products and contribute to the re-appreciation of meat products as healthy foods.

4. References


