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«INNOVATIVE TECHNOLOGIES FOR PROBIOTIC FOOD PRODUCTION»

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Abstract: *Probiotic microorganisms have attracted significant scientific and industrial interest due to their positive effects on human health and their potential role in improving the nutritional value of food products. The beneficial properties of probiotics have been recognized for more than a hundred years, and extensive research has confirmed their ability to support the balance of intestinal microflora, enhance digestive processes, and contribute to overall well-being. Despite their long history of study, the large-scale industrial application of probiotic cultures in food production has become widespread only in recent decades as a result of advances in biotechnology and food processing technologies. One of the major challenges associated with the use of probiotics in the food industry is maintaining the viability and functional activity of these microorganisms throughout production, storage, distribution, and consumption. Probiotic strains must be capable of withstanding technological processes such as heating, cooling, drying, and packaging, while also remaining stable under different storage conditions. In addition, they must survive the acidic environment of the stomach and reach the intestinal tract in sufficient quantities to provide health benefits.*

Today, probiotics are widely incorporated into various food products, including fermented dairy products, beverages, functional foods, and dietary supplements. The growing sconsumer demand for healthy and functional foods has encouraged manufacturers to develop innovative probiotic products with improved quality, safety, and effectiveness. This paper discusses the importance of probiotic microorganisms in food production, the challenges related to their application, and their growing role in the development of modern functional foods.

Key words: *probiotics, food products, meat products.*

Introduction

In the 21st century, growing awareness of health and nutrition has significantly influenced consumer preferences and purchasing behavior. Modern consumers pay greater attention to the composition, safety, and functional properties of food products, which has encouraged the development of a more transparent and consumer-focused food market. As competition within the food industry continues to intensify, manufacturers are increasingly seeking innovative approaches to improve product

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quality and gain a competitive advantage[1,2,3]. Despite the increasing demand for healthier food options, many consumers still lack sufficient knowledge about food ingredients, additives, and modern food technologies. This information gap often leads to skepticism regarding products containing additional functional components[4,5].

Consequently, food producers face the challenge of not only developing innovative products but also effectively communicating their benefits and safety to consumers. In recent years, probiotic microorganisms have emerged as one of the most promising functional ingredients due to their potential health benefits and their role in enhancing the nutritional value of food products. The growing scientific evidence supporting the positive effects of probiotics on digestive health, immune function, and overall well-being has attracted considerable attention from researchers and food manufacturers alike. As a result, probiotics are increasingly being incorporated into a wide range of food products, contributing to the rapid expansion of the functional food sector and opening new opportunities for innovation in food production. Probiotic Microorganisms[6,7,8]. History At the same time, Mechnikov believed that intestinal fibroflora was detrimental to health and needed to be replaced with lactic acid microorganisms. Somewhat later, it was discovered that yogurt contains microorganisms that protect the intestines from the destructive effects of other microorganisms. According to materials prepared and published by Lee In 1999, Salminen and Gorbach Lee used various microorganisms as probiotics due to their ability to prevent and treat various diseases. Probiotic microorganisms are available in dried or frozen form[9,10,11].

Currently, they have several potential uses: as a recipe ingredient in industrial or personal/home food production, or as dietary supplements for daily consumption.

It is most likely that the term "probiotics" was first used by Vergio in 1954, when he, in his manuscript Anti- and Probioti-ka, compared the effects of antibiotics and other antimicrobial substances on the intestinal microbial population containing microorganisms that have a beneficial effect on the intestinal microflora[12,13]. Lilly and Stillwell in 1954 defined "probiotics" as microorganisms that promote the growth of other microorganisms. There is now general agreement that "probiotics" are microorganisms that promote the development or maintain the existing balance of the autochthonous microbial population of the gastrointestinal tract (GI tract). Such microorganisms may not be permanent inhabitants of the gastrointestinal tract, but they should have a positive effect on human or animal health [14,15,16]. Later the World Health Organization.

Probiotics are living organisms that, when administered in appropriate quantities, have a positive effect on the health of the consumer [17,18]. The

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current concept of prebiotics, proposed by Cummings, Macfarlane, Englyst (2001), is based on the assumption that certain intestinal flora, such as bifidobacteria and lactobacilli, which are considered beneficial to human health, can be selectively stimulated by indigestible but fermentable carbohydrates, currently called prebiotics. Of course, to study the effect of probiotics on human health and well-being, it is necessary to study the gastrointestinal tract as a system[19,20,21]. Probiotic Microorganisms. Main Representatives According to existing information, lactic acid microorganisms are the main representatives of probiotics in both the food and pharmaceutical markets. Lactic acid microorganisms are widespread in a variety of nutrient-rich environments, such as various food substrates, manure, soil, water, and others. Some strains of lactic acid microorganisms are present in the human oral cavity, intestinal tract, and other mucous membranes and exert a beneficial effect on these human ecosystems[22,23,24]. This explains why they are ideal candidates for use as probiotics. In their pioneering work, Reuter et al. described typical lactobacilli associated with the human gastrointestinal tract. Based on their documentation, it can be assumed that homofermentative

Figure 1. Global production of food products containing probiotics

- China
- South Korea
- USA
- Malaysia
- Poland
- Peru
- Vietnam
- Russia
- Great Britain
- Taiwan

Lactobacilli typical for humans are represented by three groups: Lactobacillus acidophilus group, Lactobacillus salivarius, and Lactobacillus casei. Probiotic Microorganisms in Food Products Scientists note that creating probiotic food products is a rather complex process, as the microorganisms used must have stable characteristics of technological and clinical efficacy, clear genetic and physiological-biochemical markers, and the ability to "survive" in the product and enter the host organism viable [25,26]. For a long time, dairy products were considered the only food products with an optimal environment for probiotic development. According to authors Yu. M. Markova and S. A. Sheveleva, in 2009, the most common food products enriched with probiotic microorganisms were bio-yogurts (35% of the total probiotic food market), smoothies and fermented drinks (35.4%), bio-kefir (11.3%), and cheeses (6%) [27,28,29]. The use of probiotics in the creation of fermented milk products is a process used to extend the shelf life of milk, which remains popular among consumers [30]. As the range of this type of product continues to grow, Vicensuto and Castro examined the possibility of

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developing a new probiotic dairy product with improved antioxidant properties using mango peel as a fermentation substrate. According to the results obtained, the use of these components allowed for the production of a product with improved antioxidant and probiotic properties [31]. The scientists studied the possibility of producing probiotic yogurt from a mixture of cow's and sheep's milk. The scientists note that the highest ratio of sheep's milk to cow's milk (3:1) had a positive effect on the physicochemical parameters [32]. It should be noted that the market for probiotic products has now expanded significantly. For example, fermented vegetable and fruit juices are gaining particular popularity. In their research, Mousavi et al. developed fermented pomegranate juice; Yoon et al. developed fermented cabbage juice; K.C. de Oliveira Vieira et al., as well as Masahiro et al., examined the production of probiotic orange juice; and Hashemi, S. Hashemi, Jafarpour, and Jouki developed peach juice. The results demonstrated the potential of using various juices as a food matrix for a probiotic drink [33,34,35]. Ice cream is an equally popular dessert. Sarwar et al. examined the development of a synbiotic—Saccharomyces boulardii and inulin—in ice cream, which ensured longer shelf life and improved the product's physicochemical properties [36]. McMahon also demonstrated in their study that ice cream can be a suitable source of probiotic microorganisms such as L. acidophilus and B. bifidum. These microorganisms can remain viable during storage and grow in large numbers in the ice cream mix [37].

Chocolate has always been a popular product among both children and adults. In addition to being a delicacy, this product is a source of serotonin, tryptophan, and dopamine. Chocolate contains cocoa butter, which is rich in unsaturated and saturated fatty acids, antioxidants, and vitamins [38]. Due to this composition, scientists have considered the possibility of using probiotics in this type of product. The results of studies by Lalicic-Petronijevic, Popov-Raljic, Lazic, and others showed that a combination of three probiotic microorganism strains (encapsulated in chocolate candies) yielded a positive effect. The candies had the same functional properties and shelf life as their standard counterparts [38]. Possemiers, Marzorati, and Verstraete, studying chocolate with probiotic cultures (Lactobacillus helveticus CNCM I-1722 and Bifidobacterium longum 6NCM I-3470) using the in vitro method, were able to demonstrate that chocolate is capable of "delivering" probiotics to the large intestine [40].

Probiotic Microorganisms in Meat Products

The use of probiotic microorganisms in meat production is not yet widely developed. This is because meat products are complex, multi-component systems, where pH, temperature, water activity, and the

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presence of various chemicals (salt, sugar, flavorings, etc.) vary during production. Probiotics are most commonly used in the production of dry-cured sausages, as their production technology does not involve high-temperature heat treatment, which does not promote microbial activity. The selection of a probiotic strain is an important aspect, determining not only the viability of microorganisms in the fermented meat matrix and the delivery of probiotics to the large intestine, but also the ability of these microorganisms to withstand all technological aspects of meat production, as well as those arising directly during consumption in the upper gastrointestinal tract [41]. This requires the isolation or immobilization of heat-resistant microorganisms. The following methods facilitate the delivery of probiotics to the large intestine: encapsulation by extrusion, emulsion, spray drying, freeze-drying, and gel dispersion entrapment. These methods demonstrate the best strain stability. The choice of method depends on the type of meat product, processing conditions, storage time, and consumer preparation method. Research by scientists Sirinia, Roldánb, Lucas-González, and others has shown that the use of chestnut flour and the probiotic strain Lactobacillus plantarum GRAS can be an excellent alternative for creating a functional meat product. The resulting "synbiotic" integrated perfectly into the meat matrix—there were no changes in the product's organoleptic properties, but there was an increase in lactic acid content, which has a positive effect on the product's texture and a negative effect on pathogenic microorganisms. Chestnut flour, in addition to acting as a prebiotic, also enriched the product with polyphenols and dietary fiber [42]. In a study on the fermentation of low-fat Italian-style salami with fructo-oligosaccharides, Silva Barretto demonstrated that sodium nitrite/nitrate concentration, fructo-oligosaccharide content, temperature, pH, and salt levels negatively impacted the growth of probiotic strains. The most resistant strains were L. casei SJRP66 and L. casei SJRP169 with the addition of fructo-oligosaccharides, but slight changes in the texture of the resulting product were noted. In their studies, Nychas and Tassou examined the use of the probiotic strain Lb. plantarum L125 for the production of fermented sausages. The probiotic was added to a meat matrix containing commercial starter cultures. The effectiveness of the microorganisms was assessed during fermentation, maturation, and storage at 4 and 12 °C. Scientists note that this strain competes well with other starter cultures (S. carnosus and P. Pentosaceus) and performs well at both 4 and 12 °C. In terms of organoleptic properties, sausages produced with the above-mentioned strain have equal or better technological characteristics. In addition to finished products, scientists (Imen Trabelsia, Ben Slima, and Ktari) examined the use of a probiotic strain in ground beef (L.

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plantarum TN8). No additional food ingredients were added to the control sample, while L. plantarum TN8 was added to the test sample at a concentration of 108 CFU/g. The raw ground beef was stored for 10 days at 4°C after production. The results of the study showed that this strain positively affected color characteristics; improved the oxidative stability of lipids and proteins; and textural characteristics during storage; and also increased the microbiological stability of the ground beef samples during storage[43].

CONCLUSION

It has been established that the use of probiotic microorganisms in food production not only has a positive effect on the human body but also improves the quality of the finished product. However, a significant amount of research is devoted to the use of probiotic microorganisms in dairy production due to the specific processing techniques that create optimal conditions for their growth and development. They have not yet found widespread use in meat production, due to a number of technological and formulation factors. In the production of certain groups of meat products, starter cultures containing lactic acid microorganisms (such as L. plantarum) are used to improve the production process, allowing for the potential for increased efficiency. Therefore, research is needed to explore the potential of using starter cultures containing specific microorganisms as probiotic cultures in meat production[44].

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