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Analysis of the mutual regulation mechanism between lactic acid bacteria and yeast in fermented foods

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Abstract: Fermented foods have a long history and unique flavor, and are loved by people all over the world, among which lactic acid bacteria and yeasts are widely used in food fermentation and have an important position in the food fermentation industry. Therefore, analyzing the mutual regulation mechanism between the two can provide new ideas for the innovation of the core process of fermented food. The aim of this paper is to explore the mutual regulation mechanism between lactic acid bacteria and yeast in fermented foods, and to describe the research results at home and abroad at this stage, in order to provide innovative theoretical basis for the co-fermentation of lactic acid bacteria and yeast.

1. Introduction

The history of fermentation goes back thousands of years, and the earliest records can be found in the dietary and preservation techniques of ancient civilizations. People have mastered the use of microorganisms for food fermentation without knowing its scientific principles. In recent years, fermented foods have taken an important place in food cultures across the globe. This paper briefly describes the definition of lactic acid bacteria and yeast fermentation, focuses on the mutual regulation mechanism of lactic acid bacteria and yeast in fermented foods, and hopes to provide a reference for future research on the development of lactic acid bacteria and yeast mutual fermentation in fermented foods.

2. Basic principles of various types of fermentation

Fermentation is a biochemical process in which microorganisms convert organic matter into simpler compounds through metabolic reactions in an anaerobic or low oxygen environment. During fermentation, microorganisms utilize organic matter as a source of energy for growth and reproduction, releasing metabolites. Fermentation is also an important food processing and preservation technology that has been widely used worldwide.

2.1 Basic principles of single fermentation

Single fermentation processes can usually be divided into two main categories: alcoholic fermentation and lactic acid fermentation. Alcoholic fermentation is mainly carried out by yeast .Through fermentation, yeast is able to break down sugars into high concentrations of alcohols and gases. In addition, fermented foods are often enriched with probiotics, microorganisms that are beneficial to human health and may help maintain the balance of gut flora and support the immune system. As a result, fermented foods are gaining attention as people focus on healthy eating, and many studies are examining their health benefits and functionality.

2.2 Basic principles of co-fermentation

Co-fermentation is a food fermentation technique in which two or more different types of microorganisms work together in the same fermentation process. The process takes advantage of the properties and strengths of each microorganism in order to achieve richer flavors, improve the nutritional value of the food, or even enhance its functional properties. This type of fermentation is very common in traditional food processing and has been widely noticed and studied for its unique effects.

Through targeted selection and optimization of microbial species, setting of appropriate fermentation time and temperature, and rational matching of fermentation ingredients, food producers can create higher-quality fermented products to maximize quality, taste and nutrition[1].

Therefore, co-fermentation is a fermentation process with important economic value and scientific research significance, and through the synergistic effect of different microorganisms, it can bring a positive impact on the flavor, nutrition and safety of food products to satisfy the increasing demand of modern consumer market.

3. Fermentation Applications of Lactic Acid Bacteria and Yeasts

3.1 Lactobacillus fermentation applications

Lactic acid bacteria (LAB) are considered to be Gram-positive bacteria[2] that have an extreme growth potential to convert sugars into lactic acid and are found in nature, including animals, plants, and bacteria. Most anaerobic bacteria, both primary and secondary, can be used in a wide range of applications such as food processing, dairy production, healthcare, and many other areas.

3.2 Yeast Fermentation Applications

Yeasts are extremely tolerant and are able to carry out correct metabolic reactions in minute quantities regardless of the environment. They reproduce mainly by budding and can also form spores under adverse conditions[3]. Yeasts are widely dispersed in nature and generally grow and develop in natural environments that are rich in sugar and acidic, and use organic carbons, generally monosaccharides such as glucose, as carbon source products, often found in endocrine fluids of plants such as on fruits, vegetables and also mostly in orchard soil [4].

4. Interaction between lactic acid bacteria and yeasts and applications

4.1 Mutualistic relationship between lactic acid bacteria and yeasts

Xing et a[5]found that the addition of yeast can significantly improve the effect of lactic acid bacteria fermentation compared with growth alone, which results in a much higher growth rate of lactic acid bacteria, more stable metabolites, and a better colony structure. In addition, the action of yeast can also delay the death of the colony, resulting in better fermentation. Many interactions between lactic acid bacteria and yeast promote the growth and metabolism of organisms, but to fully utilize these effects, the mechanism of their interaction needs to be further explored.

4.1.1 Mutual influence on growth

CO2, pyruvate, propionate and succinate produced by yeast metabolism stimulate the growth of lactic acid bacteria[6]. In skimmed milk, most of the lactic acid bacteria grow better in mixed cultures than in mono-culture and as the name suggests, yeast metabolites such as pyruvates, amino acids and vitamins promote the growth of lactic acid bacteria[7].

When Lactobacillus and yeast are cultured together, there is a significant inconsistency in their growth status compared to when they are just cultured alone. The results of Wang[8] and others showed that Max Kluwer yeast was able to greatly promote the proliferation of Lactobacillus casei, thus increasing their production. Hong et al[9] showed that Lactococcus lactis was able to effectively promote the growth of Maxkluwer yeast, while different species of Lactobacillus would have an important effect on the brewing of red wine, especially under dry conditions.

The interaction between lactic acid bacteria and yeasts resulted in a significant inhibition of caseinobacteria, thus hindering their colonization. This interaction may originate from competition between the two, MENDES et al [10]who suggested that lactic acid competition between lactic acid bacteria and yeasts, thus hindering their colonization. Alternatively, they may exert inhibition by secreting metabolites that help promote their colonization. See Figure 1

4.1.2 Complementary metabolites

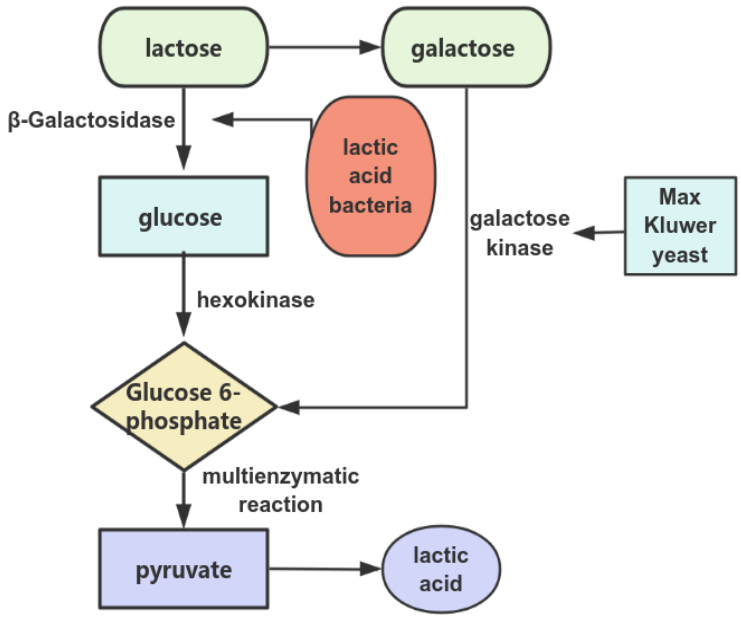

Figure 1: Lactic acid bacteria and yeasts use lactose together

Metabolic complementation mechanisms have been found to exist in various types of fermented foods, and the main reason for the existence of such mechanisms is that different microorganisms possess different enzyme systems, and since lactobacilli and yeast each lack the specific enzymes needed to break down a certain carbon source, they need to utilize the enzymatic products metabolized by the other for further reactions[11]. As shown in the figure, when lactose is used as the only carbon source, lactose cannot be utilized directly as most yeasts do not possess lactase, so α-galactosidase, which is possessed by lactic acid bacteria, is needed to break down lactose into glucose and galactose, and glucose can be utilized as a carbon source directly into the EMP pathway by most lactobacilli and yeasts, but lactobacilli lack sufficient galactokinase to further utilize galactose[12]. Involvement of Max Kluwer yeast is able to convert galactose into glucose 6-phosphate into the EMP pathway, which ultimately forms pyruvate and produces lactic acid under the action of lactate dehydrogenase, and this mechanism also explains the phenomenon that co-fermentation of lactobacilli and yeast is able to produce more lactic acid[13]. See Figure 2

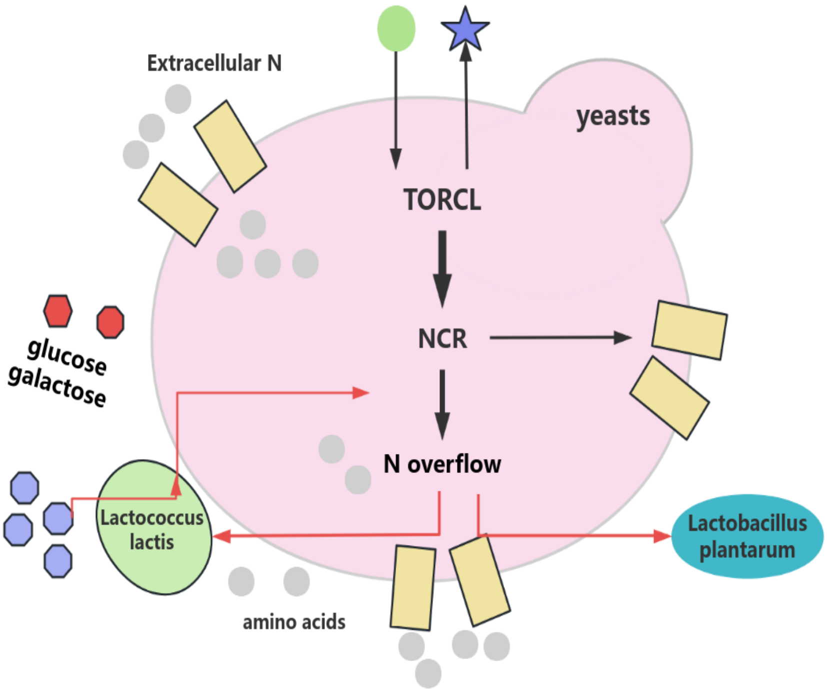

Figure 2: Lactic acid bacteria and yeast complement the metabolism of nitrogen

4.1.3 The phenomenon of group sensing

In the early days, population sensing referred to the fact that when microorganisms increase in number and their growth cycle is altered, they release one or more chemical signaling molecules that affect the physiological and biochemical properties of the microorganisms, thus indicating that only a small number of them exist as individuals.

The community sensing action system in which lactic acid bacteria become Gram-positive bacteria exists is divided into an interspecies community sensing system and a G+ community sensing system, whose informational molecules are generally either furanboronic acid diesters(AI-2) or oligopeptides(AIPs). The interspecies community sensing system is controlled by LuxS genetics and Pfs genes.The G+ community sensing system is generally divided into 2 components, the ATP-binding cassettetransporter(ABC), which is responsible for transmitting oligopeptide information molecules to the outside of the cell, and the twocomponents gnalin gsystem(TCS), which is responsible for detecting extracellular levels of information molecules and controlling them.[14]. See Figure 3

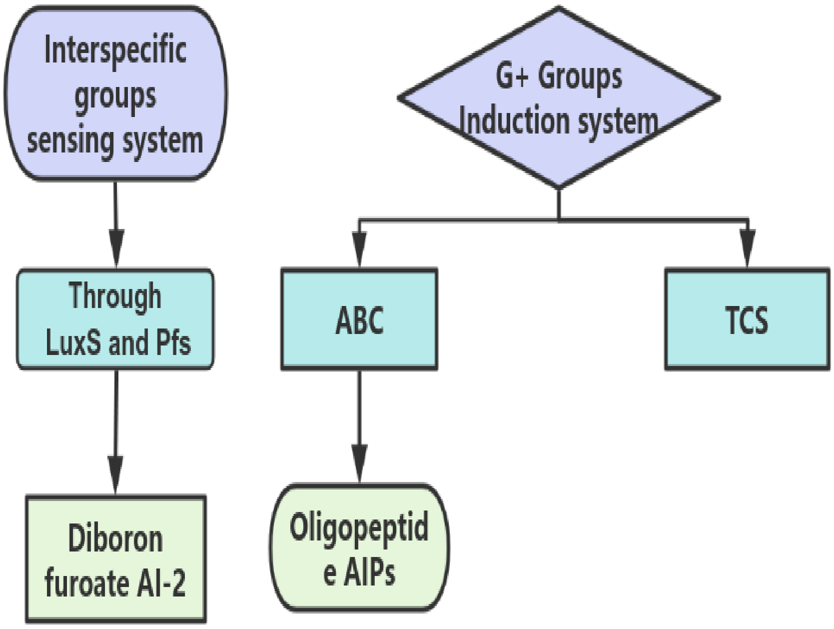

Figure 3: Interspecies quorum sensing system and Gram-positive quorum sensing system

4.2 Application of Lactic Acid Bacteria and Yeast Interaction Relationships

4.2.1 Joint fermentation of vegetables by lactic acid bacteria and yeasts

Table 1: Common fermentative microbes for pickled vegetables and their effects on product quality

Types of Pickled Vegetables	Strain used	Improvement of product quality	Ref.
Traditional pickle	*Lactiplantibacillus plantarum J05* *Sacchromyces cerevisiae Y21*	Promote the growth and reproduction of lactic acid bacteria and yeast, shorten the fermentation cycle, reduce the reduction of Raw sugar and nitrite content	[15]
Turnip pickle	*Lactobacillus plantarum* *Leuconostoc mesenteroides* *Pediococcusacidilactici* *Saccharomyces cerevisiae*	Promote the growth and reproduction of lactic acid bacteria and the production of flavor substances such as esters to enhance the kimchi flavor and quality	[16]
Northwest Sauerkraut	*Lactobacillus casei L5* *Lactobacillus paracasei L8* *Issatchenkia orientalis Y7*	Promotes acid production, shortens fermentation cycle, reduces nitrite content, and promotes flavors production	[17]
Pickle	*Lactobacillus casei L5* *Lactobacillus bulgaricus* *Lactobacillus acidophilus*	Promote the decomposition and utilization of sugars and the production of flavor substances such as esters, prevent corruption deterioration, prolong the storage period	[18]

The combined use of lactic acid bacteria and yeast can effectively improve the quality of pickled vegetables. Common pickled vegetable fermentation bacteria and their effects on product quality are shown in Table 1.Kimchi is a representative pickled vegetable in China, which is well loved by peopleAt present, the combined fermentation of lactic acid bacteria and yeast has been more widely used in the production of kimchi, in which the combined fermentation of Lactobacillus plantarum and Saccharomyces cerevisiae has a good effect and is more widely used. Zhang[15] etal. explored the effect of co-fermentation of mixed Lactobacillus powder and brewer's yeast on the quality of radish kimchi. The results showed that the moderate addition of brewer's yeast could promote the growth and reproduction of lactic acid bacteria during the fermentation process, and promote the quality of kimchi mesquite.

4.2.2 Lactic acid bacteria and yeast joint fermentation of noodle products

There are many kinds of rice and noodle products in China with different flavors and textures, which are loved by people. Xu[20] explored the mutualistic relationship of different strains of lactic acid bacteria and yeast in the joint fermentation of steamed bread. The results showed that the combined use of lactic acid bacteria and yeast helps the fermentation of steamed buns, while controlling the growth of bacteria and molds, prolonging the shelf life of steamed buns, and providing a reference for the production of high-quality steamed buns. Yan[21] studied the effect of combined fermentation of lactic acid bacteria and yeast on the quality of soda crackers. The use of lactic acid bacteria and yeast co-fermentation can significantly improve the quality and texture of rice and noodle products, prolong the shelf-life of noodle products, and also promote the production of nutrients, which is of great significance for the production of noodle products as well as the development of new functional noodle products, and has a broad application prospect. See Table 2

Table 2: Common fermentative microbes for rice and flour products and their effects on product quality

Types of fermented rice and noodle products	Strain used	Improvement of product quality	Ref.
Mi gao, a kind of rice cake	*Lactobacillus plantarum* *Saccharomyces cerevisiae* *Candida humilis*	Promote the production of volatile flavor components such as esters to enhance sensory quality	[22]
Steamed bread	*Angie's High Active Dry Yeast (Low Sugar)* *Hansen's Lactobacillus*	Promotes the growth and metabolism of lactic acid bacteria and yeast, controls the growth of bacteria and mold. Controls the growth of bacteria and molds and extends shelf life	[20]
Cracker	*Lactobacillus plantarum SQ1* *Angie's Ready-to-Produce Active Dry Yeast*	Improve protein digestibility, increase VB1, VB2 and γ-aminobutyric acid content, improve Enhance nutritional and functional properties	[21]
Multi-Grain Medley Bread	*Lactobacillus Complex Powder* *Angie's yeast*	Reduces hardness, viscosity and chewiness, improves textural properties, and promotes the production of flavor substances. and improve the sensory quality	[19]

4.2.3 Combined fermentation of soybean products by lactic acid bacteria and yeasts

Common soybean product fermentation strains and their effects on product quality are shown in Table 3.Zhao[23]explored the total ester and alcohol content in bean paste. The results showed that the total ester and other contents of bean sauce were significantly increased after inoculation of Lactobacillus plantarum and Saccharomyces cerevisiae for yeast and lactic acid bacteria co-fermentation, indicating that the co-fermentation of lactic acid bacteria and yeast significantly enhanced the quality and flavor of bean sauce, which is of guiding significance for the production of bean sauce. Zhao[24] et al. investigated the effect of the co-fermentation of Lactobacillus plantarum and Saccharomyces cerevisiae on the quality of soybean paste. Liu[25] and others explored the production process of salt-tolerant lactic acid bacteria and T yeast co-fermentation of quinoa miso, and the results showed that when the inoculation ratio of salt-tolerant lactic acid bacteria and T yeast was about 2:3, the quinoa miso obtained after 48 h of fermentation had the optimal organoleptic quality. Researchers Zhang[26] et al. explored how the combined treatment of lactic acid bacteria and yeast improved the quality of low-salt soy sauce. The results showed that it was because the total acid and total ester contents of soy sauce were significantly enhanced and biogenic amines were reduced after fermentation with lactic acid bacteria and yeast.

Table 3: Common fermentative microbes for bean products and their effects on product quality

Types of fermented soy products	Strain used	Improvement of product quality	Ref.
Doubanjiang	*Lactobacillus plantarum Saccharomyces cerevisiae*	Promotes the production of alcohols and esters, which significantly improves the quality and flavor of bean paste.	[22]
Doubanjiang	*Lactobacillus plantarum 630-MO-115 Zygosaccharomyces rouxii 625-YO-125*	Promote the production of flavor substances such as alcohols, esters and organic acids	[24]
Quinoa Miso	*Salt tolerant lactic acid bacteria Saccharomyces cerevisiae*	Enhancing the sensory quality of quinoa miso	[25]
Low-salt soy sauce	*Tetragenococcus halophilus TS71 Zygosaccharomyces rouxii A22*	Increased total acid and total ester content and decreased biogenic amine content promote alcohol and ester volatiles and inhibits the production of aldehydes and acid volatiles.	[26]

5. Summary and outlook

The study of the mutualism mechanism of lactic acid bacteria and yeast is to master and regulate the mixed fermentation process of the two, so as to be used in industrial production, to regulate the fermentation process by controlling the fermentation conditions and optimizing the fermentation substrate, and to regulate the precursors of the fermentation of the key flavor substances in order to achieve the purpose of precise flavor. From improving the sensory properties of products to enhancing the nutritional value and promoting sustainable development, future research may contribute to further revealing their rich biological mechanisms as well as practical applications in the development of food science and nutrition.

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