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Role of freeze-dried oatmeal sourdough in imparting various attributes to sourdough: A perspective

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Abstract: Sourdough contains many lactic acid bacteria, mainly including Lactobacillus sanfranscensis, Lactobacillus brevis, Lactobacillus plantarum, and a small amount of yeast, mainly Saccharomyces cerevisiae. Sourdough has many advantages; it is rich in various probiotics, improves the bioavailability of minerals through a synergistic effect on yeast, improves the nutritional value of sourdough bread, and protects the fermentation of sourdough bread from other fermentations, showing the anti-fungal effect and inhibition of microbial reproduction. Lactic acid bacteria can reduce the acidity of sourdough and inhibit the growth of harmful bacteria (Spicher, 1995). They can also reduce the low molecular weight dextrin in sourdough to inhibit the aging of bread (Lavermicocca et al., 2000), so sourdough helps to extend the shelf life of bread. The metabolites produced by the interaction between lactic acid bacteria and yeast help to increase the volume of bread and improve the texture of bread (Corsetti et al., 2000), and increase the flavor of bread (Brandt et al., 2003).With the industrialization of production and the application of instant active dry yeast, ordinary rapid fermentation technology is used to produce bread. Although bread yield has increased significantly, the quality of bread has many flaws, such as being easy to shrink and wrinkle, having poor softness, being more susceptible to spoilage, having a very short shelf life, and having a flavor that is far from traditional sourdough bread's.

1. Characteristics of sourdough

Sourdough bread in the traditional sense has a brown shell, a relatively large specific volume, fine and uniform tissue, toughness, good chewing properties, and a unique, strong sour flavor. It is a healthy food with rich nutrition and a unique flavor. Sourdough bread contains metabolites of various beneficial microorganisms, especially some polysaccharides, which have a wide range of functional properties and are of great benefit to human health (Hansen & Hansen, 1994).

Lactobacillus sanfranscensis is an important starting strain for sourdough fermentation. It belongs to the obligate heterofermentative lactic acid bacteria and is derived from the branch of Lactobacillus casei. It can produce a large amount of aliphatic amino acids, dicarboxylic amino acids, and hydroxyl amino acids, further improving product flavor. At the same time, Lactobacillus sanfranscensis is the only lactic acid bacterium with a wide range of acidification and the same type of volatility in sourdough fermentation (Schieberle, 1996). In addition to producing ethyl acetate, ethanol, acetaldehyde, and acetic acid. Important flavor substances such as n-butyraldehyde and nonanal (Hansen et al., 1989). At the same time, because Lactobacillus sanfranscensis produces acid rapidly and has strong synergistic metabolism, it has good industrial production performance.

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1.1. Oats

1.1.1. Oat glucan

Oatmeal is one of the grains with the highest nutritional value. It is rich in modern food nutrients such as protein, minerals, vitamins, and dietary fiber. The main reason is that it contains ß-glucan. It is a water-soluble non-starch polysaccharide, mainly found in oat bran, connected by ß - (1-4) and ß-(1-3) glycosidic bonds, which can increase blood viscosity in the small intestine, extend slow absorption, thereby reducing the peak plasma glucose and insulin levels after meals in diabetics and normal people, significantly lowering serum cholesterol, and preventing constipation.

Oat bran combines with intestinal water to form a jelly that increases stool weight and increases the excretion of fat in the stool. Dextran helps control appetite by slowing gastric emptying, prolonging satiety, and stabilizing blood sugar. Oat bran can alter bile acid metabolism. Although early studies found no difference between the types of cellulose, later studies have shown that oat bran, unlike wheat bran, does not protect against colon cancer. In 1997, the U.S. Food and Drug Administration (FDA) made a health claim that oatmeal can effectively lower cholesterol. Current research mainly focuses on the functional and physical properties of ß-glucan.

1.1.2. Fermentation of oat flour

There are many studies on sourdough in the world, mainly using wheat flour or rye flour as fermentation raw materials, and the research on oat fermentation is rarely reported. Wheat bran fermentation and whole grain flour fermentation have many advantages and can produce a variety of biologically active substances. Hansen and Schieberle (2005) showed that fermenting rye with heterofermentative lactic acid bacteria can increase the metabolic activity of yeast, and in 2007 studied the bioactive substances of rye fermentation, showing that mixed fermentation is better, and β-glucan interacts with itself during fermentation. cross-linked into a network structure. Studies such as Fomin's Korakli et al. (2001) showed that whole rye flour or sourdough can improve the solubility of β-glucan (Damiani et al., 1996). As the dough fermentation time increased, the molecular weight of 13. dextran decreased, but it remained unchanged during the baking process, and its content remained unchanged. Hansen et al. (1989) pointed out that the content of ß-glucan remained unchanged during fermentation, but the content of p-glucan decreased during baking. Pick et al. (1996) have shown that large wheat bran particles and short fermentation times can reduce the degradation of p. glucan. Katina et al. (2007) baked bread with whole oat flour and white flour, and its flavor was greatly improved.

1.2. Freeze drying

Freeze-drying involves pre-cooling the substance containing a lot of water to freeze it into a solid, and then directly sublimating the water vapor under vacuum conditions, while the substance itself remains in the ice shelf when it is frozen, so its volume remains unchanged after drying. Instead, it becomes loose and porous. Freeze-drying is performed at low temperatures and is therefore particularly suitable for many heat-sensitive substances without denaturation or loss of activity. The loss of some volatile components in the substance is very small, and protein microorganisms and the like will not denature or lose their vitality (Degutyte-Fomins et al., 2002).

1.2.1. Research status of freeze-dried products

Freeze-dried products have the advantages of small size, maintaining flavor and nutrition, good rehydration performance, and convenient storage and use. Instant dry yeast has been on the market for a long time, and the freeze-dried powder of the lactic acid bacteria starter of yogurt has also been on the market, but there is no research about the freeze-drying of oatmeal sourdough starter.

1.2.2. Freeze-drying protective agent

Freeze-drying is a multi-step process that produces a variety of stresses to denature the sample, such as low temperature stress, freezing stress, and drying stress. These stresses are the factors that lead to its death, and usually include the following aspects. The volume increases, and the mechanical action of ice crystals easily destroys the active sites of intracellular proteins. After some weak chemical bonds freeze, the solute concentration increases, the ionic strength increases, the pH value changes, and the phase separation occurs (Andersson et al., 2008). Freeze-drying can cause changes in the cell membrane permeability of lactic acid bacteria, protein denaturation and inactivation, destruction of the dynamic balance of pH value, DNA damage,

and changes in the composition of membrane fatty acids. Therefore, protective measures are usually taken in the preparation of starters (Izawa et al., 2007).

Many studies have shown that adding appropriate substances before lactic acid bacteria freeze-drying can play a protective role, which can improve the survival rate and preservation stability of lactic acid bacteria. The key to the success of freeze-drying for most bacteria is that an effective protective agent can change the physical and chemical environment of freeze-drying, reduce or prevent the damage of freeze-drying or rehydration to the bacteria (Oda et al., 1986).

1.2.3. Trehalose

Trehalose is a non-reducing disaccharide composed of two glucose molecules bonded by α-1,1 glycosidic bonds. It has the functions of maintaining water, inhibiting starch retrogradation, and protecting biological macromolecules (Kim et al., 2008; Van der Plaat, 1974). Under the action of external environments such as drying and freezing, the free water in the system will rapidly decrease, making the composition of the organism change from a colloidal state (crystalline state) to a glass state (amorphous state or amorphous state). The temperature at this point is called the glass transition temperature. The high glass transition temperature of trehalose is often considered to be the reason for its superiority over other sugars in bioprotection (Gadd et al., 1987).

Many studies have shown that trehalose has a particularly obvious protective effect on bacterial species, and is mainly used in Streptococcus thermophilus, Lactobacillus delbrueckii, and Lactobacillus bulgaricus. At present, there are various hypotheses about the protective effect of trehalose on biological macromolecules. There are two main mechanisms (Johansson et al., 2000). One is the water substitution hypothesis. The dehydrated parts are connected in the form of hydrogen bonds, forming a protective film to replace the lost structural water film. The other is the glass state hypothesis, which believes that trehalose has a tendency towards glass transition, and an amorphous continuous phase is formed, and the molecular motion and molecular denaturation reaction in this structure are very weak. Åman et al. (2004), Flander et al. (2007), Žlabur et al. (2021), and Han and Bischof (2004) explored the mechanism of trehalose's protective effect on yeast in the frozen dough system, and found that exogenous and endogenous trehalose also have a non-specific Protective effect (Chen et al., 2022; Yinghua, 2007) studied the effect of trehalose on the fermentation characteristics and baking performance of frozen dough (Hino et al., 1990).

1.2.4. Glycerin

Glycerin cryopreservation of bacterial strains is a skilled technology. Because glycerol itself has strong hydrophilic properties and hydrogen bond-forming ability, glycerol combines with water molecules with hydroxyl groups in the cell, reducing free water and inhibiting the formation of ice crystal molecules, reducing the mechanical damage and damage caused by ice crystal molecules to cells (Diniz-Mendes et al., 1999; Plourde-Owobi et al., 2000). Chemical damage to cells caused by changes in osmotic pressure; while increasing The concentration of the intracellular solution is determined, and the degree of glassy state is easily formed during the drying and dehydration process; secondly, the combination of hydroxyl and water molecules is used to form a stable layer of water molecules outside the cell membrane, so that the water in the cell membrane quickly enters a supercooled state during the freezing process. It does not freeze, and it is not easy to transfer outward during the drying process, which protects the structure of the cells (Van Dijck et al., 2000).

1.3. Flavor research on sourdough bread

The flavor of sourdough bread is mainly affected by many aspects, such as fermentation conditions, the production process, and raw and auxiliary materials. International research has mainly focused on sourdough bread with exogenous lactic acid bacteria. Huang et al. (2008) have shown that compared with wheat and barley, oats fermented with Lactobacillus plantarum have richer flavor substances.

It is often coupled with gas chromatography and mass spectrometry (GC-MS) techniques to analyze and identify food flavor substances (Kopjar et al., 2008). This technology has been applied to study the flavor

substances of many kinds of foods. There are more than 300 kinds of flavor substances found in bread (Salmeron et al., 2009).

2. Future Prospects

Bread is a food that is loved by everyone, and about 60% of people in the world take bread as their staple food. Oatmeal sourdough bread has the advantages of both sourdough bread and oatmeal, but no relevant research has been reported. Oatmeal sourdough starter contains many kinds of lactic acid bacteria, the main strains are *Lactobacillus sanfranscensis*, *Lactobacillus plantarum,* etc. In the long-term sourdough processing process, due to the unique environment inside the sourdough. Therefore, *Lactobacillus sanfranscensis* was used as the comparison strain in this experiment. The fermentation of *Lactobacillus sanfranscensis* has a unique flavor and can produce a variety of biologically active substances. In addition to the high dietary fiber of oat itself, it is rich in nutrition and good flavor. At present, DVI yogurt direct injection lactic acid bacteria starter and instant active dry yeast have been on the market for many years.

In the early stage of making oatmeal sourdough bread, the oatmeal sourdough starter is made by natural fermentation or by introducing bacteria into the system of oatmeal and water for fermentation. The first is to promote the further growth of bacteria to meet the needs of dough fermentation. In addition, it is fermented by simulating the dough system, which can shorten the lag period of lactic acid bacteria and achieve a better fermentation effect. Oatmeal sourdough starter has grown to be a crucial component in the production of oatmeal sourdough, but the cost is high in small batches due to the complexity of the process, so commercial production using freeze-drying methods can lower costs and make it easier to transport and use, which is conducive to large-scale. Wheat flour sourdough bread is quite extensive and mature in international research, but there are fewer reports about oatmeal sourdough bread, and wheat flour is widely used as the raw material for leavening agents. There is a lot of research on lactic acid bacteria freeze-drying, and instant active dry yeast has been on the market for a long time, but the freeze-drying protection of lactic acid bacteria in the oatmeal sourdough starter system and the research on the oatmeal sourdough starter freeze-dried product have not yet been reported. Future studies should be conducted focusing on the optimization of the freeze-drying protective agent for oat sourdough starter, the effects of dough's mechanical thermodynamic properties, fermentation rheological properties, and the effect of freeze-drying of oatmeal sourdough starter on the baking properties and flavor of sourdough bread.

CRediT authorship contribution statement

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Declaration of competing interest

The authors declare no conflict of interest.

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