

## Review Article

# Food system advances towards more nutritious and sustainable mantou production in China

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Mantou, a traditional Chinese food, is widely consumed in the North China due to its nutritional value and good mouth-feel. However, its current family-style production is impeded due to short shelf-life caused by mold and starch retrogradation. The current packaging and storage methods are not efficient enough for mantou preservation. Recently, a novel, hot online package technology has attracted attention due to its high processing efficiency and low cost. Most importantly, by using this methodology, secondary contamination by microbes can be avoided and starch retrogradation can be markedly delayed, with mantou shelf-life under room temperature extended from a few to at least 90 days without any additives. In this review, the mechanisms of mantou quality deterioration are explained and the advantages of hot package technology addressed and compared with other packaging methods, such as frozen chain storage. In this way, not only wheat, but also other grains (including whole-grains) and ingredients may be mantou constituents, to enhance nutrition of traditional mantou. There is now a technological opportunity for mantou to become a more nutritious, sustainable and affordable foodstuff in local communities.

**Key Words:** mantou, whole-grain, shelf life, starch retrogradation, hot packaging

## INTRODUCTION

Mantou, the Chinese steamed bread, is a type of tradition yeast fermented and steamed wheat product, one of the most popular staple foods in Chinese diet, and accounted for around 70% of wheat consumption in North China.<sup>1</sup> Mantou is rich in nutrition and high in moisture content. Thus, it is easily deteriorated because of microorganism effect, which may cause serious food safety problems.

From production to consumption, mantou will go through four steps: processing, transportation, storage and marketing, which take a long time. The mantou preservation and shelf-life extension, thus, face a great challenge. The two critical reasons for mantou deterioration are staling and mold, which delay the industrial transition of mantou from family-style production.<sup>2-4</sup> Mantou staling, also referred as hardening, is commonly defined as the loss of freshness (mouth-feel, flavor and moisture loss) during storage, which leads to the decrease of shelf-life and in the meantime is a great waste of wheat and also an economic waste. Mantou staling is mainly caused by starch retrogradation. The manufacturers have tried different methods to control it, such as enhancing the fermentation process,<sup>5,6</sup> slowing down the water loss,<sup>7</sup> and using additives such as oil, enzymes, emulsifiers, etc.<sup>8</sup> But, all these methods have disadvantages as they are less-effective and require a high energy input.

Mantou mold is mainly caused by secondary contamination with microbes. It has been reported that after 20 hours (hrs) storage in an ordinary condition, the aerobic bacterial population of fresh steamed bread went up to 10<sup>5</sup> CFU/g, which was associated with a peculiar smell and sticky filaments. Mold could be seen clearly after 30

hrs storage.<sup>9</sup> Several methods have been tried to solve the problems, such as using longer heating treatment for better sterilization; using clean (sanitation) flour to avoid microbes and insect eggs which could cause rancidity and flavor loss in the flour and its products;<sup>10</sup> keeping the production and storage environment disinfected by frequently using UV light and air purify units to prevent the product from contamination. However, none of these methods have effectively and completely eradicated the contamination.

This review summarizes the nutritional values, the staling and microbiology control of mantou products during storage as well as novel packaging technologies targeting the nutritious and sustainable mantou production in China.

## NUTRITIONAL VALUES OF MANTOU PRODUCTS

### *Protein*

The protein in mantou comes from wheat flour, thus the quality of wheat flour affect mantou protein significantly. The major proteins in wheat flour include glutenin, gliadin, globulin, albumin, among which glutenin and gliadin are dominant proteins to form gluten. The composition of protein in wheat has a great influence on the quality of

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mantou. Correlation studies have been conducted between protein composition and mantou quality. The quality of dough for mantou can be improved with optimized ratio of proteins.<sup>11</sup> An analysis of 14 wheat flours used for producing 3 different mantou showed that different staple mantou required different protein content. Soft mantou requires protein content of 10.0%-12.5%, while 10.7%-13.5% protein is required for hard mantou.<sup>2</sup>

### **Carbohydrate**

The carbohydrates in mantou include starch, low molecular sugars and dextrin. These are predominant ingredients in traditional Chinese mantou and they have a great influence on mantou quality while providing energy for human metabolism. It has been shown that a high ratio of amylopectin and amylose and a high damaged starch content play a positive influence on mantou quality.<sup>12</sup>

There are negative correlations of the diameters of starch granules type A and type B, and also those of the diameters of starch granules type B with thermal properties. Significant positive correlations between DA and thermal properties, as well as the relationships of peak temperature and enthalpy were observed; the content of the associated protein is significantly and negatively correlated to the type B starch granules, whereas weakly and negatively to the type B.<sup>13</sup>

### **Lipid**

Lipid content is around (1~2)% (w/w) in wheat flour, but it is of great importance for gluten formation; for example, lecithin can make wheat flour fine and smooth and delay starch retrogradation.<sup>14</sup>

The specific volume and stomatal quantity of mantou made from weak defatted weak gluten wheat flour increased; medium and high gluten defatted flour materials have decreased specific volume and stomatal quantity. Lipid cannot prevent starch retrogradation but will delay this process.<sup>15</sup>

## **STALING CONTROL OF MANTOU DURING STORAGE**

### **Quality of mantou**

Many criteria have been established to describe mantou quality. That most used is derived from the Chinese standard SB/T 10139-93. Both exterior and interior properties including the specific volume (mL/g), appearance, various aspects of the crumb colour, structure, elasticity, cohesiveness, stickiness, and odour are all quality attributes. The quality of mantou is mainly decided by the chemical composition of the wheat flour as well as its processing methods. For example, the protein content,<sup>16</sup> the amount of total starch and mechanically damaged starch,<sup>17</sup> different wheat milling process,<sup>17</sup> as well as some optional ingredients such as emulsifier (diacetyl tartaric acid ester of monoglycerides) and some enzymes (xylanase and  $\alpha$ -amylase)<sup>8</sup> are all quality related.

### **Quality change of mantou during storage**

The quality of mantou is highly affected by storage time. Both the physicochemical and sensory properties of mantou decrease with storage time in an obvious manner.<sup>1</sup>

The staling of mantou includes crumb firming, toughening and loss of flavour and moisture; other sensory parameters also dropped drastically including softness, stickiness, cohesiveness, elasticity, taste and total score. The shrinkages are mainly attributed to starch retrogradation.

Starch, as the major component of mantou, consists of two major molecular components, amylose and amylopectin. The steam heating could result in gelatinization of the starch with the loss of the crystalline structure and for the starch becoming amorphous. The amorphous starch chains, however, will interact with water and each other to undergo retrogradation, resulting in the structural firming. The retrogradation is contributed by both amylose and amylopectin of starch, but can be separated into two steps: amylose re-association is related to the short-term retrogradation during the initial few hours, amylopectin re-crystallisation is associated with product firming in the longer term.<sup>8</sup>

Water content in mantou is highly associated with its quality. Moisture migration from crumb to crust in bread has been related to staling of western bread. However, according to Sha et al<sup>8</sup> moisture migration in mantou during storage was different from that of western bread: as mantou does not have dry crust due to the steam process. The skin of mantou had higher moisture content (41.5%) than center crumb (39.3%) after cooking, which was opposite to that of baked bread. The skin moisture then gradually decreased with storage time (Figure 1). However, if we use the hot packaging method (as mentioned in part 5 of the review), the moisture migration will be avoided, leading to longer shelf life of mantou during storage.

For general storage and transportation process, low temperature (4°C) is usually applied to avoid microbes. However, low temperature speeds up the retrogradation process of starch<sup>18,19</sup> by enhancing the formation of crystalline structures of both amylose and amylopectin, leading to rapid crumb formation. The hot packaging methods allow the mantou products to be stored and transported at room temperature, since the bacteria, have mostly been killed during steamed hot packaging process. Therefore, the shelf life of hot packaging mantou will be highly improved.

## **MICROBIOLOGICAL CONTROL OF MANTOU PRODUCTS**

Wheat flour is the main raw material for producing mantou products. The microbes of wheat flour come from the wheat before and after harvesting, including not only the planting but also the processing of wheat, such as the cleaning of wheat flour. The microorganisms will proliferate immediately and lead to the degeneration of the final product once the processing conditions are subjected to unsuitable operations; thus it is very important to control the microbes in wheat flour by strict processing operations. Advancement of food science and technology and food hygiene have resulted in declining of microbial and chemical food infection or toxicosis has lead to improved hygienic quality of flour; an exception is fungal contamination of foods.<sup>20</sup> New technologies play an important role in the microbial control of wheat flour. Ozone treated

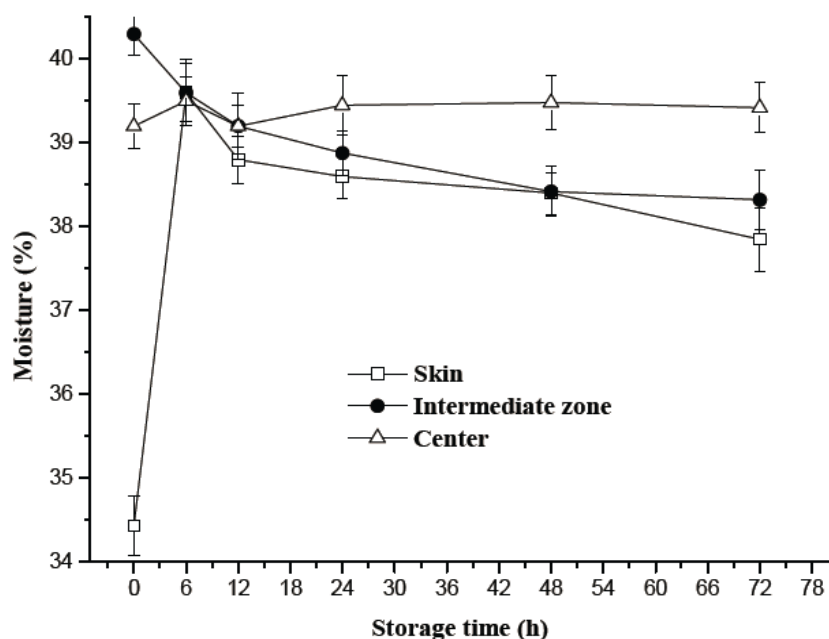


Figure 1. Water migration of mantou with storage time, adopted from Zhu (2014).<sup>8</sup>

wheat flour decreases the number of microorganisms during storage.<sup>21</sup> It has been also reported that gamma irradiation can be used to decontaminate flours.<sup>22</sup>

Mantou products are a typical fermented food, so that microbes play an important role in the processing of mantou products. In the factory, a single yeast is used in mantou industry as culture starter, which is easier to be used than sourdough. The mathematical modeling of yeast fermentation was studied on the base of expansion of a pseudoplastic foam. Quite good agreement was observed between experimental data and model parameters.<sup>23</sup>

The sourdough still accounts for a great share in usage of starter because of the irreplaceable sensory quality of fermented mantou products.<sup>17,24</sup> Microbial status inside the sourdough is the base of industrialized production of mantou products. Sourdough is made by fermentation of flour with yeasts from natural environment. In fact, sourdough is a synergistic fermentation system containing multiple microbial strains. Besides the yeast, there are numbers of other microbes in sourdough,<sup>25</sup> thus sourdough is rich in microbial enzymes. The saccharifying power, the liquefying power and the fermenting power of sourdough are apparently beneficial for the fermentation of yeast in mantou products.<sup>26</sup> The mantou products produced by the fermentation of single yeast is poor in flavor compared with mantou fermented by sourdough. Researchers previously studied the health benefits of breads containing whole grains or functional ingredients rich in dietary fibre and  $\beta$ -glucans.<sup>27</sup> Sourdough bread showed better potential over yeast-fermented breads when a blend of whole-wheat flour and oat bran was used. We have separated the yeasts from different sourdoughs collected in China.<sup>28</sup> The contributions of different yeast strains to the original flavor of mantou products fermented by sourdough will be investigated in future.

With the progress of research in the microbiology of sourdough, formula standardization and the standardized

production in mantou products, the stability of sourdough has been queried and should be reassessed in mantou industry. The quality of some leavened, sourdough-baked goods is not always consistent, unless a well-propagated sourdough starter culture is used for the dough fermentation.<sup>21</sup> However, the fine sensory quality of mantou products produced by sourdough fermentation is well known. At the same time, usage of sourdough makes it possible for sourdough industrialization. The mechanization of sourdough processing has been developed to automate the supply of dried sourdoughs to the bakery industry. Some of the dough is fermenting during several hours to develop a pleasant aroma.<sup>29</sup>

Compared with yeast in sourdough, lactic acid bacteria have the advantage of numbers. In the studies of sourdough production, lactic acid bacteria were inclined to be chosen as microbiological factor. In assessment of comparative methods for storing type-I wheat sourdough, frozen storage enabled a partial preservation of the starter lactic acid bacteria for 90 days and for obtaining bread with a quality approaching that produced through sourdough not subjected to storage.<sup>30,31</sup> The lactic acid bacteria play different roles in processing sourdough. Maize sourdoughs were made by fermenting maize flour with multiple strains starter culture and with *Lactobacillus plantarum*. Sourdough fermentation of maize dough brought about a (25-26)% increase in loaf volume of maize bread.<sup>32</sup> It is important to screen lactic acid bacteria with higher stress resistance in processing. In the work of Anna et al (2015), 108 *L. paracasei*, 68 *L. rhamnosus* and 8 *L. casei* strains, isolated from different sources and geographical regions were screened for tolerance to acid, bile salts, high osmolarity and capability to grow at different temperatures and survival after exposure to refrigeration or freezing. There were 13 strains which showed better tolerance to the above stresses, which will be potentially useful in sourdough processing.

In processing mantou products, three times fermentation technology as well as the two times fermentation are used. Pulp fermentation, sourdough fermentation and mantou fermentation are the common steps involved in mantou production. Corn, wheat and/or salt may be added into the material to accelerate the fermentation in the first step, microbial amylases are produced rapidly associated with an apparent increase of microbial numbers. In fact, some contaminant microorganisms could enter into the ecosystem. With the pH decreased, the lactic acid bacteria and yeast become the dominant microbes. There is a great variety of yeast species found in sourdoughs,<sup>29</sup> while the most common bacterial genus is *Lactobacillus*.<sup>33</sup>

#### NEW TECHNOLOGY IN MANTOU PROCESSING

Packaging has been applied to help mantou preservation and protection from contamination. Mantou products in the market can be generally classified into sealed package mantou and simple packaging mantou. The former, due to the isolation from environment results in a longer shelf-life, while the latter, simply packaged using plastic material without being isolated from the environment completely, on the other hand, has a relatively shorter shelf-life.<sup>21</sup> However, since both methods use room temperature packing style, it is easy to lead to secondary contamination. Some manufacturers have employed the frozen preservation method, which could extend the shelf-life up to 6 months. This method, however, is limited by the production cost, as it will consume more energy and need freezer equipment as well, because the temperature needs to be controlled under  $-18^{\circ}\text{C}$ .<sup>34,35</sup> Another drawback is that the quality of mantou quality will somewhat decreased during frozen storage. For example, the hardness increased by 0.9%; the chewiness decreased by 28.6% compared with 10.7% decreases under room temperature storage. The elasticity, stickiness and recovery also will be decreased to some extent.<sup>36</sup>

Hot packaging technology is a newly developed technology that can be used for the storage of mantou at room temperature. Two challenges need to be met during hot packaging: the water vapor will condensed inside the package and the packaging bag will expand because of heat. But, the unique advantage is that it can protect against contamination, and save space without cooling. For mantou processing companies, hot package technology can significantly increase processing efficiency and reduce costs.

To solve the problems of the short storage time, mold growth at room temperature storage, retrogradation in steamed bread production, and also to meet the requirements of safety and convenience, as well as industrialization, there is promising data from the technology using traditional yeast for fermentation, combined with online-pasturing-hot-packing technology to produce Chinese traditional steamed bread. The results showed that the microorganism index, including *Staphylococcus aureus* and *E. coli*, met the requirements of the national standard. In addition, there was no significant change in protein content, moisture content, fat content, and starch retrogradation, as measured using X-ray diffraction.<sup>37</sup>

By utilizing this technology, water vapor disappeared after three days storage, without leading to water conden-

sation on the surface, thus having a similar effect as vacuum packaging. This technology saved energy consumption and minimized secondary contamination during transportation and retailing. The mantou packaged by this technology can be maintained fresh up to 90 days without any additives, giving good taste along with least starch retrogradation.<sup>37</sup>

#### ALTERNATIVE GRAINS, WHOLE GRAINS AND INGREDIENTS

For nutritional purpose, many minor grain flour or powders including grinding, extrusion and ultra-fine powder of black rice, buckwheat, red bean, waxy wheat flour have been used in the recipe<sup>38,39</sup> for mantou processing. The acceptable amount of ultrafine black rice powder, buckwheat, and red bean ranged from 20% to 30%, waxy wheat flour at 15%. Any increases beyond these amounts resulted in negative effects on the mouth feel, surface structure, surface color, interior structure and comprehensive scores, chewiness, and springiness. Extrusion, comparing with grinding and ultra-fine processing, was a better choice to keep the texture of gluten matrix.<sup>38</sup> According to previous research,<sup>40-43</sup> minor grain mantou containing 30% corn powder or 45% millet powder, or 20% sorghum flour, or 25% buckwheat flour in the recipe all could achieve an acceptable quality.

Ten different colorful fruit and vegetables materials were evaluated for inclusion in the mantou recipe, and according to the sensory evaluation analysis, the red jujube, carrot, pumpkin, purple sweet potato results clustered together, while spinach, maize, tomato, celery, and green tea were clustered together, and black sesame was categorized into a third cluster. It was also reported that red jujube steamed bead and black sesame steamed bread had the best and worst properties by the sensory evaluation, respectively.<sup>44</sup>

The whole grain cereals considered were rich in dietary fiber, non-starch polysaccharides, and many bioactive components,<sup>45,46</sup> but the amount of the fiber restricted the gluten network formation and the dough become sticky; for example, the expansion ability of whole meal mantou was reduced significantly.<sup>46</sup> To overcome these processing technology problems, the vacuum-atomization dough making technology, biotechnology enzyme technology, physical field processing technology can be used to enhance processing characteristics, improve the quality of whole meal food,<sup>46</sup> and meet the increased requirements from consumers.

#### FUTURE PERSPECTIVES

The innovative technology of hot-online-packaging can be used not only for Chinese steamed products, but also be used for western style food packaging, such as baked bread, pan-cake, and other starch-based foods, including their fillings. This technology has recognized by an Innovation award of the Chinese Food Science and Technology Institute in 2014. The hot package technology may help the food industry, especially local food manufacturers, to produce better quality products with less waste and at reduced cost. Moreover, its suitability for diverse grains and wholegrain products has the capacity to improve the nutritional status and health of the population,

who consume mantou or similar steamed food products in China and beyond.

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#### AUTHOR DISCLOSURES

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### 在中国粮食体系馒头生产朝着更营养和可持续发展的方向发展

馒头因营养佳、口感好，是中国北方地区广泛消费的传统主食。但市场上馒头因霉菌污染和淀粉老化问题而严重地影响了货架期，目前常用的包装和贮存方法已不能满足馒头的保藏需求。最近，一种高效实惠的新型馒头在线包装技术引起了市场的普遍关注。该方法可同时实现控制馒头的二次污染和延缓淀粉老化，在不添加任何食品添加剂的条件下馒头可常温下保鲜从几天延至 90 天。本综述介绍了馒头的品质劣变机理，并将热包装与传统的冷链贮存进行了技术对比分析。采取热包装技术，不但可进行小麦馒头的生产，而且还可添加较多的全谷物面粉以及其他谷物原料生产全谷物馒头，改善其营养价值。无菌在线热包装技术已成为中国新的营养、可持续以及实用的新型加工技术。

**关键词：**馒头、全谷物、货架期、淀粉老化、热包装