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Research Article

Effects of Food Additives on Drying Rate, Rehydration Ratio and Sense Value of Freeze-dried Dumplings

Xingli Jiao, Xiang Gui, Hua Li and Ying Xiong
School of Chemical and Energy Engineering, Zhengzhou University, No. 100 Science Road, Zhengzhou, Henan 450001, China

Abstract: Dumpling has always been a traditional and delicious food in China. Nevertheless, the rehydration effects, especially the nip of dumplings, are far from people's satisfaction. To solve this problem, in this study, aimed at the improving the rehydration properties of freeze-dried dumplings, three kinds of food additives, including compound phosphate, soybean lecithin and guar gum, were added into dumplings wrappers. Results showed that, the drying rate, rehydration ratio and sense value were the highest with respective addition of 0.1% compound phosphate, 0.6% soybean lecithin and 0.35% guar gum. The interactions between freeze-dried dumplings and food additives were discussed, which provided the theory foundation for preparation of freeze-dried food.

Keywords: Drying time, dumplings, food additive, freeze-dry, rehydration ratio, sense value

INTRODUCTION

Dumpling, also called "Jiaozi" in China, is a delicious food that consists small lumps of dough that are cooked and eaten, with meat and vegetables. Dumplings are not only the most widely loved traditional food in China, but also a worldwide famous delicacy. With the development of people's living standers and fast-paced life, the instant dumplings have attracted more and more attraction from people. It is well know that conventional drying (hot air) may affect the quality of a product. Compared with the traditional drying ways, the freeze-drying products were able to ensure food protein, vitamins and other nutrients, especially those who are not volatile loss of heat-sensitive components and maximize their original nutrients and can inhibit the harmful effects of bacteria and enzymes to effectively prevent the drying process of oxidation. Nevertheless, the cost of the freeze-dried food is high and the rehydration effects, especially the nip of dumplings, are far from people's satisfaction. To solve this problem, in this study, aimed at the reducing energy consumption and improving the rehydration properties of freeze-dried dumplings, some food additives were added into dumplings wrappers and the effects of food additives on drying rate, rehydration ratio and sense value of freeze-dried dumplings are researched (Lin *et al*., 2010; Zhang *et al*., 2010).

The vacuum freeze-drying technology, also called lyophilization or FD, is one of the most advanced among all the drying methods. Moisture is removed from foods with low temperature, lack of oxygen and no contact with light, which makes foods maintain original color, taste, shape and active ingredients after being freeze-dried (Deng and Gu, 2004; Shen and Cui, 2006). If this technology is applied to ready-to-eat dumplings, not only dumplings can retain traditional advantages of fresh dumplings, but also this technology can overcome a series of problems that exist in quick-freezing dumplings. Shao and Xiong (2006) prepared freeze-dried dumplings and determined the main parameters of this process, including pre-freezing rate, loadage, vacuum degree and drying temperature with rehydration ratio being the index. However, as dumplings contain much starch, which will retrograde during pre-freezing, so the rehydration ratio and flavor of freeze-dried dumplings are not unsatisfactory, which is a non-negligible trouble and limits the development of freeze-dried dumplings (Du *et al*., 2006). It was reported that suitable food additives can solve the problems above. Liu *et al*. (2012) studied the effects of six food additives, including fucose, hydrogenated starch hydrolysates, dextrin, sucrose, sorbitol and fructooligosaccharide, on the rehydration ratio of freeze-dried cooked squid and gained the best combination from single factors and orthogonal experiments, which largely improved the rehydration properties of freeze-dried cooked squid. So in this study, some food additives were added into dumplings to improve unsatisfactory rehydration properties and imperfect taste of freeze-dried dumplings, which can provide some guidance for the industrialization of freeze-dried dumplings.

Corresponding Author: Hua Li, School of Chemical and Energy Engineering, Zhengzhou University, No. 100 Science Road, Zhengzhou, Henan 450001, China, Fax: 0086-371-63886154

Table 1: Standards of quality assessments of dumplings

Items	Standards	Full marks
Color	It refers to the color and luster of dumplings. Cream, ivory or white is 16-20 points; common luster is 11-15 points and the bad luster and gray color is 1-10 points.	20
Flavor	Wheat fragrance is 16-20 points, no peculiar smell is 11-15 points and peculiar smell is 1-10 points.	20
Viscosity	It refers to the stickness of dumplings when tasting. Refreshing and with little stickness is 16-20 points, a little refreshing and stickness is 11-15 points and no refreshing and much stickness is 1-10 points.	20
Smoothness	It refers to the smoothness of dumplings when chewed. Smoothness is 16-20 points, a little smoothness is 11-15 points and little smoothness is 1-10 points.	20
Palatability	It refers to the force to chew dumplings. Moderate force is 16-20 points, a little hard or soft is 11-15 points and too hard or soft is 1-10 points.	20

MATERIALS AND METHODS

Materials and instruments: Wheat flour is produced by Huaxue Grain and Oil Processing Co., Ltd. The vacuum freezing dryer LGJ-12S is produced by Huaxing Technology Development Co., Ltd. Songyuan Beijing corn. Composite phosphate is produced by Hengshi Food Co., Ltd in Xuzhou. Guar gum is produced by Hengshi Food Co., Ltd in Xuzhou.

Soybean lecithin is produced by Tianxing Food Co., Ltd in Henan. All of three food additives were of food grades. Fresh pork, fresh fragrant-flowered garlic, eggs, salt and cooking oil were from local market.

The processing of freeze-dried dumplings:

The preparation of dumplings: Take out of the flour (300 g) in a stainless steel pot, add water (38% Wt), mix them together for 15 min and the dough with moderate hardness is prepared. Then place the dough in a plastic bag to ferment for 40 min. At the same time, chop fresh pork and fresh fragrant-flowered garlic into pieces and put an egg in specific proportion. When the ferment time of dough comes, make dumplings wrappers with diameter being about 5 cm, put the fillings on wrappers and knead the edge, then a dumpling is perfectly made. Cook the dumplings in boiled water for 7 min and then dry them in the air for 20 min.

The freeze drying of the dumplings: Load the dumplings on four trays of the freezing dryer, with the load age of 3.33 kg/m^2, then put the trays on a shelf and freeze them in the cold trap of the freezing dryer. After 3 h, take the dumplings into the freeze-drying chamber. And then, the vacuum pump is turned on and the heating button is pressed when the pressure is below 15 Pa. The dumplings are dried at 45°C. While the temperature of the dumplings is close to room temperature and changes slightly at room temperature, the process of the freeze-drying is finished.

The drying rate (%/h) can be calculated according to the following formula (Chen and Liu, 2002):

$$F = 100 \times \frac{M_1 - M_2}{M_1 \times t} \tag{1}$$

In which,

M_1 = The initial mass of dumplings before freeze-drying, g

M_2 = The mass of dumplings after freeze-drying, g

t = The drying time, h

Weigh the freeze-dried dumplings, then rehydrate them in the boiled water for 8 min, then weigh them again and calculate their rehydration ratio. The rehydration ratio can be calculated through the following formula (Wang *et al*., 2005):

$$R = \frac{M3}{M2} \tag{2}$$

In which, M_3 is the mass of the dumplings after rehydration, g.

The sense value of the frozen dumpling wrappers: The sense values of the freeze-dried dumplings are evaluated according to the standard SB/T 10138-93 (Ma *et al*., 2008). Dumplings are observed and tasted by evaluation group consisting of fifteen people and the quality of the dumplings is scored according to Table 1. The final score is regarded as the average of the scores.

RESULT ANALYSIS

The conditions of the additive experiments were as followings: water addition 38%, boiling time 4 min, rehydration time 8 min, pre-freezing time 3 h, drying temperature 45°C and loadage per unit area 3.33 kg/m^2; the masses of the compound phosphate were 0.05, 0.075, 0.1, 0.125 and 0.15%, respectively; the masses of soybean lecithin were 0.2, 0.4, 0.6, 0.8 and 1.0%, respectively; the masses of guar gum were 0.251, 0.3, 0.35, 0.4 and 0.45%, respectively.

Effects of compound phosphate on drying rate, rehydration ratio and sense value of freeze-dried dumplings: Phosphate is most widely used in food industry in the world and plays an important role in improving food quality, for example the water holding capacity, gelation strength and the rate of finished meat product or meat protein. Furthermore, Wu Xuehui has confirmed compound phosphate can improve quality of noodles and strengthen viscoelastic and rigidity of noodles (Chen, 2004). The ingredients of composite phosphate used in this study were Sodium

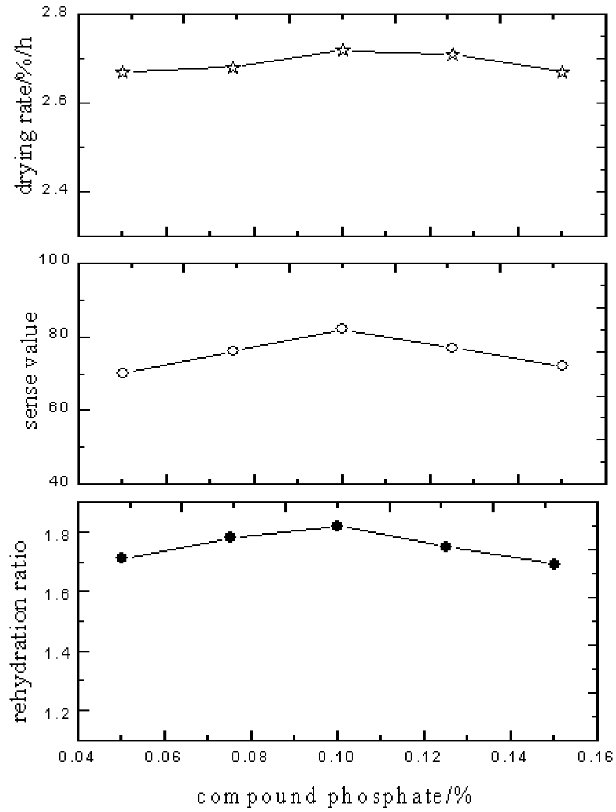

Fig. 1: Effects of composite phosphate on drying rate, rehydration ratio and sense value of freeze-dried dumplings
☆, ● and ○: Drying rate, rehydration ratio and sense value of freeze-dried dumplings, respectively

Tripolyphosphate (STPP), sodium pyrophosphate, calgon, disodium hydrogen phosphate, sodium phosphate, tertiary and sodium acid pyrophosphate, which are of food grades (Li *et al*., 2001). The effects of composite phosphate on drying rate, rehydration ratio and sense value were shown in Fig. 1.

Seen from Fig. 1, when composite phosphate addition was lower than 0.1%, with the increase of composite phosphate addition, the drying rate, rehydration ratio and sense value of wrappers all increased, which might result from the capacity of phosphate to build a bridge between gluten and starch and form a stable complex (Li, 1995). Moreover, phosphate makes water holding capacity of starch stronger and protein swell much sufficient, which helps to form dense and regular gluten network structure, thus ensuring that water could escape from structural channel easily and regular channels were better for the rehydration ratio and sense value of dumplings. Besides, when composite phosphate addition increased, the interaction between phosphate and protein reinforced and quantity of protein net charge increased, making mutual repulsion between protein molecules stronger and improving water retention.

When composite phosphate addition was higher than 0.1%, with the increase of composite phosphate addition, drying rate, rehydration ratio and sense value all decreased gradually, which might be due to the complicated physicochemical properties of composite phosphate. When the composite phosphate was dissolved in water, it could be ionized into Na^+ and various phosphate ions completely and these ionized phosphate ions could be hydrolyzed at the same time. These reactions would change water activity and the ionized Na^+ could combine with hydroxyl group in starch molecule to change the properties of starch gelatinization. Therefore, the formation of regular gluten network structure will be affected severely.

On the other hand, when the concentration of phosphate was exorbitant, the pH value will deviate from the best pH value at which water retention is formed and this may result in protein denaturation and loss of partial water (Zhang *et al*., 2005). At the same time, exorbitant concentration of phosphate may cause Ca/P ratio in human body to be out of balance and initiate multiple complications. Therefore, drying rate, rehydration ratio and sense value all decreased and the best addition of compound phosphate is 0.1%.

Effects of soybean lecithin on drying rate, rehydration ratio and sense value of freeze-dried dumplings: Soybean lecithin is a kind of natural surfactants with satisfactory performance, the main

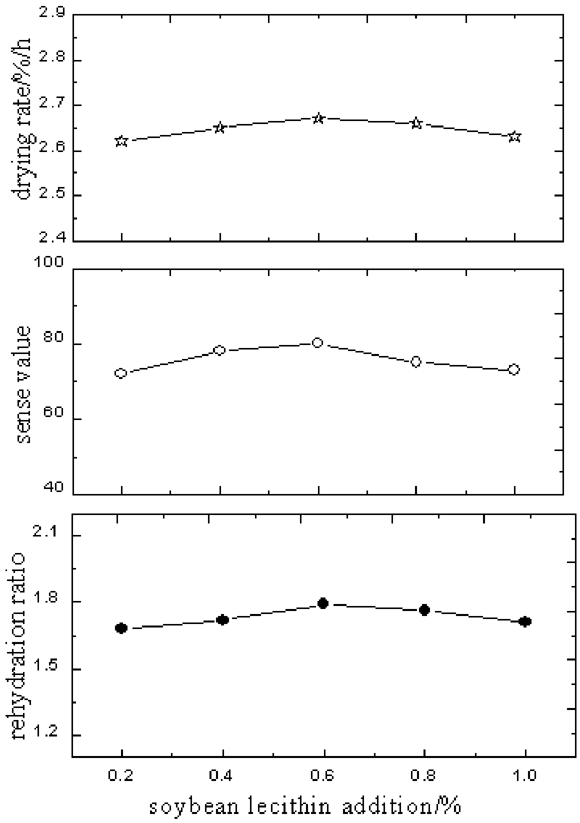

Fig. 2: Effects of soybean lecithin on drying rate, rehydration ratio and sense value of freeze-dried dumplings

ingredients are Phosphatidyl Choline (PC), Phosphoryl Ethanolamine (PE), Phosphoinositide (PI), Phosphoric Acid (PA), triglyceride and vitamin and it cannot be dissolved in acetone (Dong, 2007). Phosphate groups and choline groups, belonging to hydrophilic groups, are from internal soybean lecithin molecular and two oelophilic fatty-acid chains are on external surface, thus making it very easy for soybean lecithin to form reverse micelle (Wang, 2003). Its specific molecular structure determines its capacity to disperse, emulsify, active surface, prevent starch from aging and being oxidized. Soybean lecithin has been widely used in baking food, noodles, candies, chocolate, ice cream and margarine and meat products. The effects of soybean lecithin on drying rate, rehydration ratio and sense value were shown in Fig. 2.

Figure 2, when soybean lecithin addition was lower than 0.6%, with increase of soybean lecithin addition into freeze-dried dumplings, drying rate, rehydration ratio and sense value increased and 0.6% of soybean lecithin addition gave the best rehydration properties and sense value. This might be because soybean lecithin can interact with polar material as well as non-polar materials in wheat flour by its capacity to active surface: hydrophilic groups can be combined with gliadin while oelophilic groups can be combined with gluten (Pan and Gu, 2007). At the same time, soybean lecithin has a synergistic effect on the integration of protein and lipid, which helps to accelerate the cross-linking of gluten and increase the capacity of protein to emulsify. On the other hand, soybean lecithin can form complex with amylose molecular, thus preventing amylose molecular from adhering to each other and the aging process being stopped (He *et al*., 2007). So drying rate, rehydration ratio and sense value all increased.

Yet, when soybean lecithin addition was 0.6~1.0%, drying rate, rehydration ratio and sense value all decreased, which may result from the complicated interaction of soybean lecithin with protein and lipid. When soybean lecithin addition is excessive, it will be easy for soybean lecithin to form reverse micelle, which will have a bad effect on the adsorption of soybean lecithin for water. Even protein peptide chain coats protein in the inner side of network structure, which affects water adsorption, thus making water adsorption ratio reduced. Furthermore, the excessive soybean lecithincan hinder formation of S-S bond between protein, weakening the strength of dough and can generate a waxy taste, affecting its sense value (Li *et al*., 2007). Besides, oelophilic groups in soybean lecithin may act with certain lipids and partial protein may dissolve, disintegrating partial network structure. So drying rate, rehydration ratio and sense value all decreased and the best addition of soybean lecithin is 0.6%.

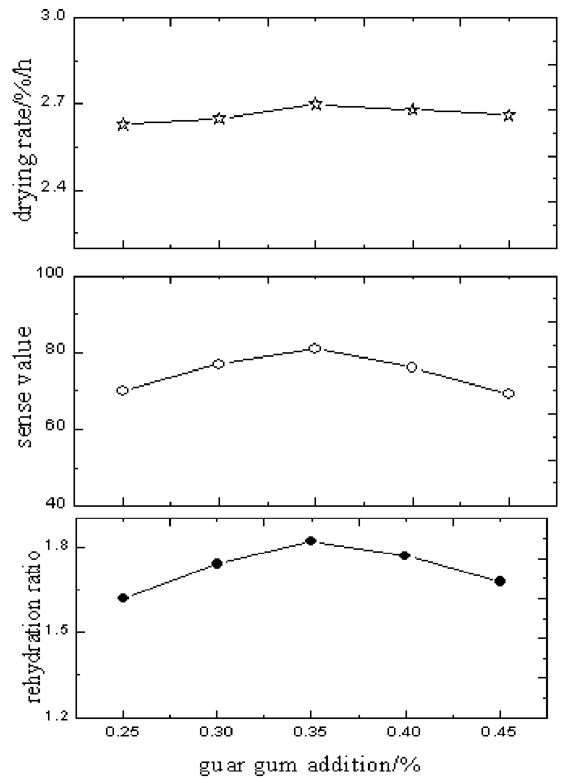

Fig. 3: Effects of guar gum on drying rate, rehydration ratio and sense value of freeze-dried dumplings

Effect of guar gum on drying rate, rehydration ratio and sense value of freeze-dried dumplings: Guar gum, also called guanidine gum, is one of cheapest and most widely used colloid. (1, 4)-β-D-mannose unit forms the main chain and α-D- galactose unit is linked with main chain by (1, 6)-glucosidic bond in main chain every two mannose units are connected with a galactose unit on average and the proportion of mannose and galactose is about 2:1 (Gu and Liu, 2010). Guar gum belongs to swelling polymer and it can combine with plenty of water, making it used widely in food industry. Usually, it served as thickener in wheaten food as guar gum can form molecular clusters with protein with starch inlaying in the net structure, which helps to form a dense and regular structure. Therefore, guar gum can improve aging phenomenon of starch resulting from crystallization of amylose. Guar gum has good water-solubility whether in cold water or hot water as well as crosslinking capacity. Yet, when applied to solid food, it has strong water absorbency and can work as water retaining agent. Zheng *et al*. (2010), studied the effects of several food additives on quality of instant noodles with vegetables and it was found that when added with guar gum, toughness and springiness of the noodles decreased explicitly; the surface was smooth; cooking quality was better and sense value was greater. Wu (2009), succeeded in increasing quantity of gluten by adding guar gum into dough. On this basis, guar gum was chosen to add into dumplings to improve the rehydration properties and sense value and the effects of guar gum on the drying rate, rehydration ratio and sense value of freeze-dried dumpling were shown in Fig. 3.

Seen from Fig. 3, with increase of guar gum addition into freeze-dried dumplings, drying rate, rehydration ratio and sense value increased first then decreased and 0.35% of guar gum addition gave the best rehydration properties and sense value. When guar gum addition was lower than o.35%, due to effects of emulsification and gelation, guar gum can reduce the loss of soluble protein and prevent flavor compounds from leaching. At the same time, the regular and dense network structure formed by guar gum together with gluten protein net structure, can cocoon starch granules completely and form very inerratic structure which could not only prevent the loss of starch granules on the surface of dumplings when boiled, but also assist the escape of water released, as well, it was conducive to the escape of gas released. So guar gum can improve drying rate, rehydration ratio and sense value of freeze-dried dumplings.

Yet, when guar gum addition was over 0.35%, it would hinder the mutual interaction of amylase (Lin *et al*., 2011); glue taste of guar gum was extremely strong; viscidity of dumplings would increase when boiling; gas permeability would get disappointed and the dumplings were easy to crack, resulting in the decrease of drying rate, rehydration ratio and sense value of freeze-dried dumplings. Therefore, guar gum addition was best chosen to be 0.35%.

CONCLUSION

The effects of three kinds of food additives, including compound phosphate, soybean lecithin and guar gum, on drying rate, rehydration ratio and sense value were studied in this study in order to improve the rehydration properties and sense value of the freeze-dried dumplings. Results showed that all of the three food additives could improve the rehydration properties, drying rate and sense value. The interactional mechanism between food and additives were also analyzed. Food additives can interact with protein and starch to form more regular and denser network structure. Composite phosphate can build a bridge between gluten and starch and form a stable complex and strengthen water holding capacity of starch, which is favorable to form better structure; soybean lecithin can interact with polar material as well as non-polar materials in wheat flour by its capacity to active surface and accelerate the cross-linking of gluten and increase the capacity of protein to emulsify; guar gum can reduce the loss of soluble protein and prevent flavor compounds from leaching and cocoon starch granules completely due to its effects of emulsification and gelation. Furthermore, with respective addition of 0.1% compound phosphate, 0.6% soybean lecithin and 0.35% guar gum in freeze-dried dumplings, drying rate, rehydration ratio and sense value were the highest. Among three food additives, the effects of compound phosphate and guar gum on rehydration properties were greater than that of soybean lecithin.

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