Advance Journal of Food Science and Technology 8(6): 440-445, 2015
DOI:10.19026/ajfst.8.1541
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: December 26, 2014 Accepted: February 5, 2015 Published: June 10, 2015

Research Article

Study on Freeze-drying Process of Dumpling Wrappers

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Abstract: The freeze-drying process of frozen dumpling wrappers is studied in this study. And the effects of drying time, drying temperature and the capacity of unit area in the freezing process on the drying rate and rehydration rate of freeze-drying dumpling wrappers are investigated. The result shows that, in the process of freeze-drying dumpling wrappers, the optimal condition is: drying time is 3 h, drying temperature is 45°C and the loadage of per unit area is 4.0 kg/m^2.

Keywords: Drying rate, dumplings, dumpling wrappers, rehydration rate, vacuum freeze-drying

INTRODUCTION

Dumpling, also called “Jiaozi” in Chinese, is a food that consists of small lumps of dough that are cooked and eaten, with meat and vegetables. Dumplings are not only the most widely loved traditional food, but also the world famous delicacies. Because the chopped meat in the dumplings contains large amount of moisture, this causes much inconvenience during storage, transportation, sales and cooking. But the freeze-drying food in food industry develops quickly and has become a newly-developed industry (Wang *et al*., 2009). We adopt an advanced vacuum freeze-drying technology to remove the water in food. The freeze-drying depends on sublimation principle to work under vacuum pressure, so that the water in the material can be frozen without ice melting. What’s more, the ice sublimate directly into gas in the vacuum distillation. Moreover, in the technology of vacuum freeze-drying, we are sure that food protein, vitamins and other nutrients, especially the heat-sensitive food who contains the volatile components, can maximize their original nutrients and inhibit the harmful effects of bacteria and enzymes to effectively prevent the drying process of oxidation. The freeze-drying food can be preserved for a long term and easy to transport because of the light weight (Chan, 2003; Fang and Lv, 2007; Wang and Zhao, 2010; Xiao *et al*., 2008). But the vacuum freeze-drying technology of dumplings is somewhat complicated, because the dumplings contain not only the dumpling wrappers made by flour, but also the stuffing, including meat, vegetables and condiment, etc., leading to their rheological properties and complicated frozen process. Therefore, we study the conditions of freezing process of frozen dumpling wrappers firstly in order to provide technical basis for production of the freeze-drying dumplings.

METHODOLOGY

Materials and instruments: The Wheat flour is produced by Huaxue Grain and Oil Processing LTD. The vacuum freezing dryer is LGJ-12S, produced by Huaxing Technology Development LTD. Songyuan Beijing.

The process of frozen dumpling wrappers:

The preparation of dumpling wrappers: Take flour of 300 g into a stainless steel pot, add water (40% Wt), mix them together for 15 min and the dough of moderate hardness was prepared. Then place the dough in plastic bag and roll out to thickness of about 3 mm and length of 5 cm, then cook the wrappers in boiling water for 7 min, then dry them in the air for 20 min (Lin *et al*., 2010).

The freeze drying of the wrappers: Load the wrappers on four trays of the freezing dryer, with the loadage of 4 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 wrappers 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 wrappers are dried at 45°C. While the temperature of the wrappers is close to the room temperature and is changed little at room temperature, the process of the freeze-drying was finished.

The drying rate (%/h) can be counted as follows (Chen *et al*., 2002):

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$$F = 100 \times \frac{M_1 - M_2}{M_2 \times t} \quad (1)$$

In which,
M_1 = The initial mass before freeze-drying, g
M_2 = The mass after freeze-drying, g
t = The drying time, h

The rehydration of the wrappers: Weigh the wrappers after freeze-drying and then rehydrate them in the boiling water for 18 min and then weigh them again and calculate their rehydration ratio. The rehydration ratio can be counted as follows (Wang *et al*., 2005):

$$R = \frac{M_3}{M_2} \quad (2)$$

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

RESULTS AND DISCUSSION

The effects of the wrappers' prefreezing time on the freeze-drying rate and the rehydration ratio: Under the condition that water addition is 40%, the boiling time is 7 min, rehydration time is 18 min, drying temperature is 45°C and the loadage of unit area is 4 kg/m^2, when prefreezing time is 1, 2, 3, 4 and 5 h, respectively, the effects of prefreezing time on the freeze-drying rate and the rehydration ratio were studied, which are shown in Fig. 1 and 2 correspondingly.

It can be seen from Fig. 1 and 2, that freeze-drying rate increases first and then decreases with the increase of prefreezing time, while the rehydration ratio increases first and has little change later. When the prefreezing time is 3 h, the freeze-drying rate is highest and the rehydration ratio also reaches the highest, with little change later.

If the prefreezing time is too short, the material can't be frozen completely and there will be a little liquid water existing. In the vacuum state while being dried, these water will evaporate quickly, which influences the product structure to make the product cannot form loose and porous state evenly in the drying process, obstructing the hole channel where the moisture sublimated and escaped, therefore, the drying rate reduced.

At the same time, as the material is not frozen thoroughly, the material will partially melt and collapse with the gradual increase of heating temperature in the drying process, which influences the rehydration of freeze-drying products. But if prefreezing time is too long, the energy consumption for refrigeration and load will greatly increase. With the increase of prefreezing time, prefreezing temperature will decrease to the freezing point of material and then the crystal nucleus is

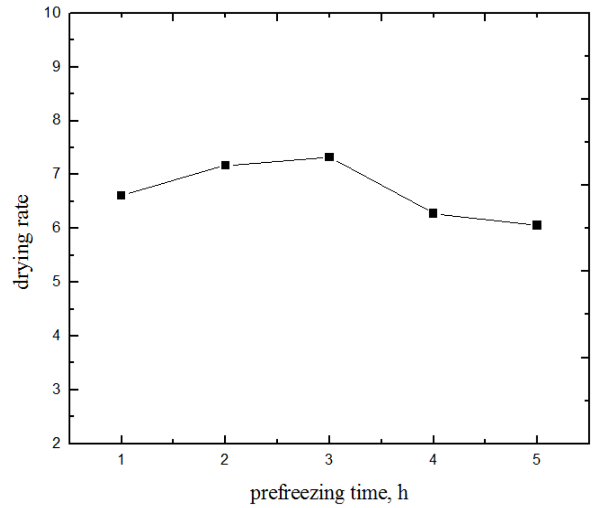

Fig. 1: The effect of prefreezing time on the freeze-drying rate

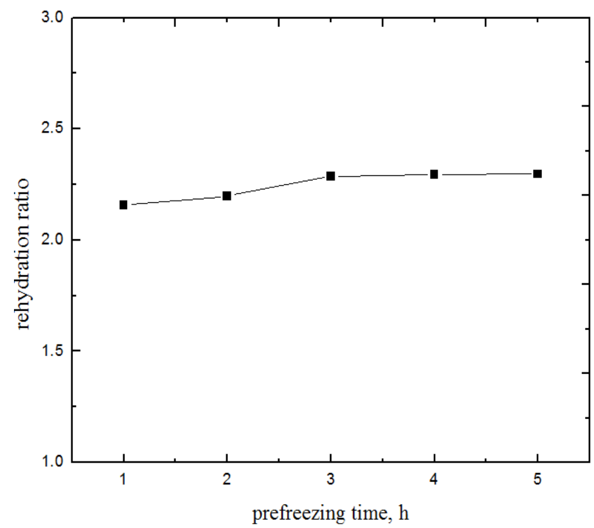

Fig. 2: The effect of prefreezing time on the rehydration ratio

formed. In the freezing process, because the frozen ice increases, the solute concentration of unfrozen phase is improved continuously.

Theoretically, the material and its inner water should have formed eutecticum at eutectic point. But for most complicated materials, it's hard for the solute to be crystallized completely at eutectic point. Along with the further increase of prefreezing time and the decrease prefreezing temperature, more and more ice is formed and the solute concentration of unfrozen phase goes higher, until the maximum concentration while the temperature reaches the glass-transition temperature. Then, the unfrozen phase forms the glass state and the whole material forms a complicated solid structure which contains both ice crystals and vitreum. Cool it again, the temperature will fall below the glass-transition temperature, but the concentration won't be larger. The larger the glass-transition concentration, the

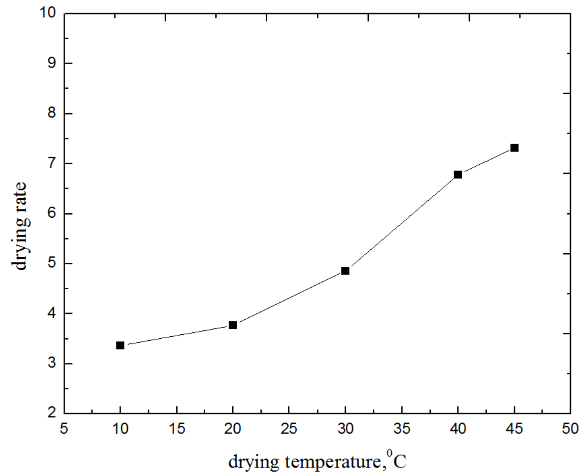

Fig. 3: The effect of drying temperature on the wrappers' drying rate

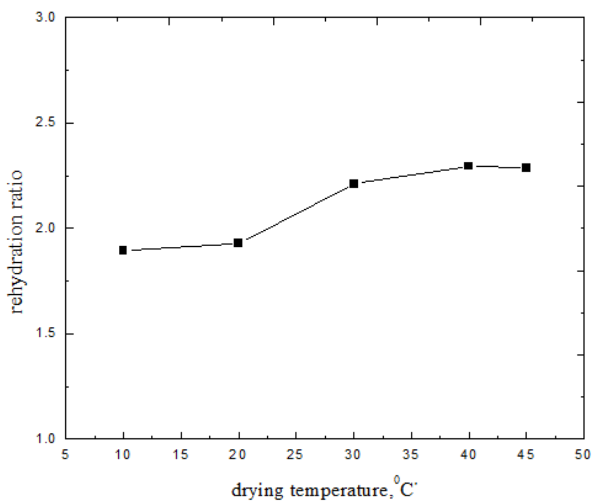

Fig. 4: The effect of drying temperature on the wrappers' rehydration ratio

higher the corresponding glass-transition temperature (Slad and Levine, 1994; Hua, 1995).

In the drying process, the longer the prefreezing time of material, the more the frozen ice, the higher the solute concentration of unfrozen phase and even the glass transition concentration. Glass-transition concentration increases with the increase of its corresponding glass transition temperature. Therefore, at the beginning of the stage, if drying temperature is relatively low, the drying rate will be low correspondingly. But if the prefreezing time is long, material will be frozen thoroughly, then the molecular mobility is rather small, so the stability of the material can be easy to maintain and the material melts and collapses less. Thus it can maintain loose and porous state and the rehydration of frozen products is good.

The effects of the wrappers' drying temperature on the freeze-drying rate and the rehydration ratio: At the condition that water addition is 40%, the boiling time is 7 min, rehydration time is 18 min, prefreezing time is 3 h and the per unit area loadage is 4 kg/m^2, the effects of drying temperature on the freeze-drying rate and the rehydration ratio while the temperature is 10, 20, 30, 40 and 45°C, respectively were investigated.

The effect of drying temperature on the drying rate of the wrappers is shown in Fig. 3. It can be seen from Fig. 3 that drying rate increases with the increase of drying temperature. And when the drying temperature is 45°C, the drying rate is the largest. This is because the higher the temperature, the more the heat energy transferred from the frozen layer, the higher the driving force of mass transfer and the higher the escape rate of water and the faster the drying rate.

The effect of drying temperature on the wrappers' rehydration ratio is shown in Fig. 4.

It can be seen from Fig. 4 that, the rehydration ratio increases firstly and then decreases slightly with the increase of temperature. When the temperature is 40°C, the rehydration ratio of the wrappers is the largest. The reason is that when the temperature is low, the heat energy transferred to the frozen layer from shelf will be less and the driving force of mass transfer is small. So, the moisture in the wrappers can't be dried thoroughly and some water is held back in the hole channels for water escape, which may directly influence the rehydration rate of food. When the temperature reaches 45°C, the wrappers will partially melt and disintegrate, thus, the structure and quality of dumpling wrappers are influenced and the rehydration ratio will decrease slightly.

The effect of loadage of per unit area on drying rate, the output of per unit area and unit time and rehydration of freeze-drying dumpling wrappers: The loadage of per unit area has a great effect on drying rate and rehydration ratio of freeze-drying dumpling wrappers. If the loadage of unit area is small, the energy consumption will be large. Therefore, taken comprehensive consideration of the energy consumption and working hours, the output of unit area and unit time is selected as evaluated standard.

On the condition that water addition is 40%, the boiling time is 7 min, rehydration time is 18 min, prefreezing time is 3 h and the drying temperature is 45°C, the effects of loadage of per unit area on the freeze-drying rate and the rehydration ratio while the loadage is 3, 3.5, 4, 4.5 and 5 kg/m^2, respectively were investigated.

The effects of loadage of unit area on the drying rate, the output of unit area and unit time of the wrappers are shown in Fig. 5.

It can be seen from Fig. 5 that, the less the loadage of per unit area, the higher the drying rate. It is because if the loadage of per unit area is less, the piling thickness of wrappers is thinner, the hole channels of

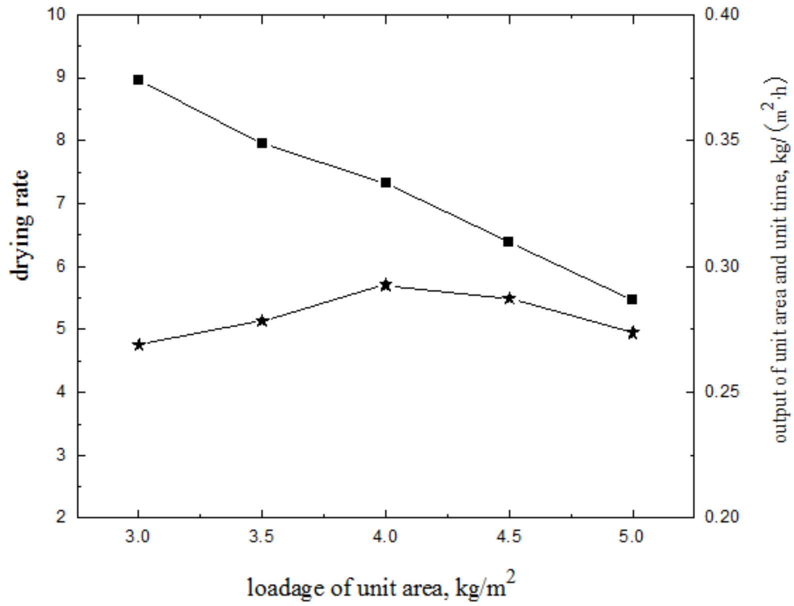

Fig. 5: The effects of loadage of unit area on the drying rate, the output of unit area and unit time of the wrappers
■: Drying rate (%/h); ★: Output of unit area and unit time (kg/ (m^2·h))

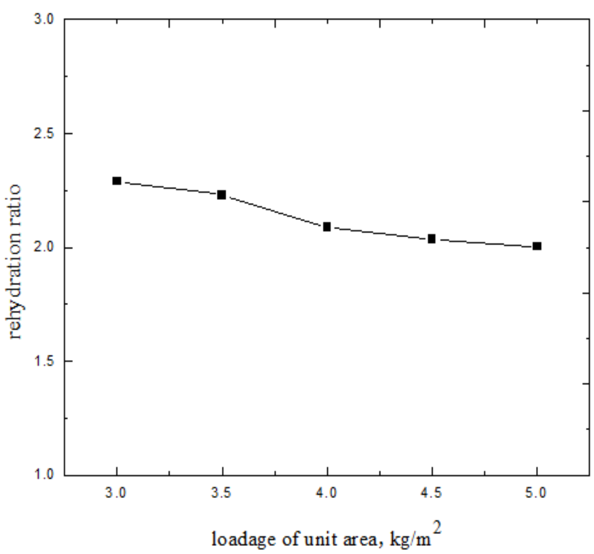

Fig. 6: The effect of loadage of unit area on the rehydration ratio of freeze-dried dumpling wrappers

Table 1: The factors and levels for the orthogonal experiment

Factor	Prefreezing time (h)	Drying temperature (°C)	Loadage of unit area (kg/m^2)
1	1	35	3.5
2	2	40	4.0
3	3	45	4.5

water vapour escape is shorten more and the mass transfer resistance is less, so the drying rate is improved. But the output of unit area and unit time increases firstly and decreases later with the increase of loadage of per unit area and when the loadage of per unit area is 4 kg/m^2, the output reaches the peak.

The effect of loadage of unit area on the rehydration ratio of freeze-drying dumpling wrappers is shown in Fig. 6.

It can be seen from Fig. 6 that, with the increase of the loadage of per unit area, the rehydration ratio of the freeze-drying wrappers decreases gradually. The reason is that the loadage of per unit area is large, the piled thickness of wrappers is thicker, the escape time of steam is bigger and the mass transfer resistance increases, the moisture in the wrappers can't be dried thoroughly and the steam is hold back in the hole channels for long time, which may cause wrappers partially melt and disintegrate and influence the rehydration ratio.

The effects of prefreezing time, drying temperature and loadage of per unit area on the drying rate, output of unit area and unit time and rehydration ratio of the freeze-drying dumpling wrappers: Based on the experiments of single factor above, we found that the prefreezing time, drying temperature and the loadage of per unit area are the main factors. In order to study the effects of these factors on drying rate, output of unit area and unit time and rehydration ratio of freeze-drying dumpling wrappers to find the optimal conditions, the orthogonal experiments including three factors and three levels were designed and carried out, which are shown in Table 1, The experimental results based on the orthogonal array L_9 (3^4) are listed in Table 2.

From the results of drying rate shown above, it can be seen that the most important factor is drying temperature and then in sequence is loadage of per unit

Table 2: The orthogonal experiment results

No.	Prefreezing time	Drying temperature	Loadage of unit area	Result 1 (drying rate)	Result 2 (output of unit area and unit time)	Result 3 (rehydration ratio)
1	1	1	1	6.509	0.2278	2.2512
2	1	2	2	6.291	0.2516	2.1630
3	1	3	3	6.876	0.3094	1.9107
4	2	1	2	6.006	0.2402	2.1853
5	2	2	3	6.114	0.2751	2.3095
6	2	3	1	8.208	0.2873	2.2959
7	3	1	3	5.879	0.2646	2.2843
8	3	2	1	8.114	0.2840	1.9158
9	3	3	2	7.318	0.2927	2.3376
K11	6.559	6.131	7.610	-	-	-
K12	6.776	6.840	6.538	-	-	-
K13	7.104	7.467	6.290	-	-	-
R1	0.545	1.336	1.320	-	-	-
K21	0.263	0.244	0.266	-	-	-
K22	0.268	0.270	0.261	-	-	-
K23	0.280	0.296	0.283	-	-	-
R2	0.017	0.052	0.022	-	-	-
K31	2.108	2.240	2.154	-	-	-
K32	2.264	2.129	2.229	-	-	-
K33	2.179	2.181	2.168	-	-	-
R3	0.156	0.111	0.075	-	-	-

area and prefreezing time. The optimal conditions for drying rate are that prefreezing time is 3 h, drying temperature is 45°C and the loadage of per unit area is 4.0 kg/m^2.

From the results of output of unit area and unit time shown above, the order of three factors in sequence is: the drying temperature ‹loadage of per unit area› prefreezing time. The optimal conditions for output of unit area and unit time are that prefreezing time is 1 h, drying temperature is 45°C and the loadage of unit area is 4.5 kg/m^2.

From the results of rehydration ratio shown above, the order of three factors on rehydration ratio is: prefreezing time ‹drying temperature› loadage of unit area. The optimal conditions for rehydration ratio are that prefreezing time is 3 h, drying temperature is 45°C and the loadage of unit area is 4.0 kg/m^2.

In conclusion, taken comprehensive consideration of energy consumption, working hours and the quality of the wrappers, the output of unit area and unit time and rehydration ratio were selected as the evaluation indexes to find the optimum conditions. The optimal conditions were that prefreezing time is 1 h, drying temperature is 45°C and the loadage of unit area is 4.5 kg/m^2, but the rehydration ratio is only 1.9107. what't more, if prefreezing time is only 1 h, the wrappers are not frozen completely, which may influence the following drying process and rehydration process. Therefore, we determine the optimal experimental conditions for freeze-drying dumpling wrappers are that the prefreezing time is 3 h, drying temperature is 45°C and the loadage of unit area and unit time is 4.0 kg/m^2.

CONCLUSION

The frozen dumpling wrappers with high drying rate, good rehydration and good taste have successfully prepared with the vacuum freeze-drying technology. The freezing process of frozen dumpling wrappers was studied and the related factors were investigated. The result shows that the drying rate increases firstly and decreases later with the increase of prefreezing time, but the rehydration ratio of freeze-drying dumpling wrappers increases firstly and then keeps constant. When the prefreezing time is 3 h, drying rate and the rehydration ratio are the highest.

The drying rate increases with the increase of drying temperature and when the drying temperature is 45°C, drying rate is the maximum. And the rehydration ratio increases with the increase of drying temperature, then shows a slight downward trend, when the drying temperature is 40°C, the rehydration ratio of frozen dumpling wrapper is the largest.

Along with the decrease of loadage of unit area, the drying rate gradually increases, but the rehydration ratio of frozen wrappers decreases gradually. The output of unit area and unit time increases with the increase of the loadage of unit area and then decreases later. When the loadage of unit area is 4 kg/m^2, the output is the largest.

With energy consumption, man-hours and the quality of the wrappers taken into comprehensive consideration, the optimum condition for the freeze-drying process of dumpling wrappers is that the prefreezing time is 3 h, the drying temperature is 45°C and the loadage of unit area is 4.0 kg/m^2.

ACKNOWLEDGMENT

The authors thank the financial support from the national undergraduate innovation and entrepreneurship training plan (201410459011).

REFERENCES

Chan, X.G., 2003. The analysis of factors on the quality of quick-frozen dumplings. Meat Ind., 24(7): 23-25.

Chen, C.G., J.J. Liu and D.S. Chen, 2002. The effect of blanching on the drying of the tender pod of snow peas. Food Sci. Technol., 28(10): 16-17.
Fang, X.X. and X.D. Lv, 2007. The research of application of vacuum freeze-drying technology. Food Drug, 9(8): 57.
Hua, Z.Z., 1995. The Research of Rapid Cooling of Amorphous State Curing in Low Temperature Biological Medicine. Science Press, Beijing, pp: 96-104.
Lin, M.G., L. Ding and G.Z. Zhao, 2010. The effect of modified starch on the quality of quick-frozen dumplings. Cereal Feed Ind., 33(5): 18-19.
Slad, L. and H. Levine, 1994. Glass Transitions and Water Food Structure Intersections. Academic Press, San Diego.
Wang, F.F. and C. Zhao, 2010. The application and development of FD technology in the food industry. Acad. Periodical Farm Prod. Process., 6(3): 63-65.
Wang, F.C., Q. Fang and X.L. Zheng, 2005. The research of freeze-drying wonton. Cereal Feed Ind., 28(12): 27.
Wang, L.L., Q.Y. Lu and X.L. Zhang, 2009. The effect of different drying methods on noodle's quality. Food Sci. Technol., 34(5): 167-169.
Xiao, X., L. Ren and D.H. Zhang, 2008. The processing of freeze-dried food and its prospective market. Agr. Eng. Technol., 3(7): 25-26.