Comparison of Puffing Characteristics for Blackcurrant Slice Obtained by Microwave and Microwave-vacuum Method *

Liu Chenghai　Zheng Xianzhe

(*College of Engineering*, *Northeast Agricultural University*, *Harbin* 150030, *China*)

Abstract

A comparative puffing experiment on blackcurrant slice between the microwave and microwave-vacuum method was performed. During microwave puffing process, microwave intensity was 20 W/g and initial moisture content of blackcurrant slice was 35%. While the initial conditions were the same with that for microwave puffing method except for 30 kPa vacuum pressure during the microwave-vacuum puffing process. The conclusion was obtained that for microwave-vacuum puffing technology, the expansion ratio was first increasing and then almost in constant. The puffing process was in the accelerating dehydration period in first 10 s, and subsequently kept the constant dehydration phase. While during microwave puffing process, the expansion ratio and dehydration rate were first increasing and then decreasing. The anthocyanin content of blackcurrant slice obtained by the microwave-vacuum method was higher than the microwave method. Therefore, the microwave puffing characteristics combining with vacuum technology were superior to that produced at the atmosphere pressure.

Key words　Blackcurrant slice, Microwave, Microwave-vacuum, Puffing

CLC number: TS255.36

Document code: A

Article ID: 1000-1298(2011)S0-0194-05

Introduction

Blackcurrant fruit (*Ribes nigrum* L.), which is mainly growth in central and northern Europe and northern Asia[1], riches in an extraordinary high vitamin C (181 mg/(100 g)) and vitamin B_5 content (398 mg/(100 g)), as well as lots of potassium, phosphorus, iron, etc[2]. Moreover, there are more than 15 species of anthocyanins[3], unsaturated fatty acids[4] and polyphenols[5], so the blackcurrant fruit has certain health benefit such as inhibiting heart disease and cancer, as well as anti-aging[6]. The blackcurrant fruit is becoming more and more popular for people of all ages. However, it is difficult to store fresh fruit due to high moisture content itself. Therefore, the fresh blackcurrant fruit is usually used for deep processing, such as the preparation of juice, jelly, jam and other food products[7].

Puffed food as a type of snack food is favored by consumers due to the crisp and delicious taste. In addition, there is a long self-life for the puffed food because of low moisture content. A conventional method to produce puffed food is a frying or baking method. However, these processes may result in the decomposition of anthocyanin and vitamin C[8~9], as well as the residue of edible oil and the formation of harmful substance to human health such as acrylamide[10] due to the puffing food is necessary to subject to the period of high temperature. Microwave technology can be also used as a puffing method. Microwave energy can penetrate into food and produce a volumetrically distributed heat source because of the friction of moisture molecular and iron caused by dipole rotation of a polar solvent in response to the change of electric filed[11]. Thus, the water in the food will evaporate with thermal energy increasing. Internal evaporation can generate significant pressure, which results in the expansion of food volume[12]. In addition, there are also some researchers to employ microwave method combining with vacuum technology to produce the puffing food, such as blue honeysuckle[13], apples[14], dough[15], bighead carp slices[16] and blackcurrant[17].

The objective of this study is to compare the

Received date: 2011－08－05　Accepted date: 2011－08－26

* Supported by National Natural Science Foundation of China (31071579) and Key Program of Natural Science Foundation of Heilongjiang Province (ZD201013)

Biography: Liu Chenghai, lecturer, majored in value-added processing of agricultural product, E-mail: liuchenghai@neau.edu.cn

Corresponding author: Zheng Xianzhe, professor, majored in value-added processing of agricultural product, E-mail: zhengxz@neau.edu.cn

differences in expansion ratio, moisture change (moisture content and dehydration rate) and anthocyanin content of blackcurrant slices during microwave puffing process combining with and without vacuum technology.

1 Material and Method

1.1 Material and Pretreatment Process

Fresh blackcurrant fruits were purchased from the local agro-produce market. Removing the impurities and incomplete fruit, and washing the whole blackcurrant, then smashing these fruit by Philip Juicer in order to prepare blackcurrant pulp. Because the pure pulp can not be swelled according to the pre-experiment, three types of starch were added to the pulp at the total mass percent of 30% according to potato: waxy rice: corn starch at the mass ratio of 2:1:1, and then the mixture was stirred uniformity using stirrer. In order to get the good taste, the mixture pulp needs to be heated about 2.5 h in a water bath at a temperature of 70℃ as so to remove moisture and gelatinize starch. Then knead it for 10 ~ 15 min until obtaining uniform blackcurrant dough. The blackcurrant dough was processed into the desired shape that was a round shape of (12.24 ± 1.0) mm radius, (2.84 ± 0.2) mm thickness and (1.46 ± 0.03) g weight. Then the round slices were dehydrated with 50℃ in hot-air drying test bed until they reached moisture content of 35%. Finally, these slices would be used in microwave and microwave-vacuum experiments.

1.2 Microwave-vacuum Puffing Experiment

Microwave-vacuum puffing operation was carried out in a microwave-vacuum dryer with six rotary suspended baskets showed as Fig. 1 (Guangzhou Kewei microwave energy Co., Ltd., China). According to preliminary experimental results, the experimental conditions of microwave-vacuum method were set at 30 kPa vacuum pressure, 0.93 kW microwave power and 20 W/g microwave intensity. In order to obtain the given microwave intensity, 32 slices of blackcurrant were required for every experiment, in which four baskets contained 5 slices, while the other two baskets had 6 slices respectively. Experimental data were measured every 10 s, and then the experiment was restarted until the time more 10 s than last experiment so as to assure the accuracy of data. When the final moisture content of blackcurrant slices reached 10%, the whole process was over.

1.3 Microwave Puffing Experiment

Microwave puffing experiment was operated in WD700 microwave oven (Tianjin Lejin electric equipment Co., Ltd.). In order to compare the differences of puffing properties between microwave-vacuum and microwave puffing technology, the setting parameters were the same between these puffing processes except the environmental pressure, that is, the microwave intensity of 20 W/g, the initial moisture content of blackcurrant slice was 35%. The experimental process and measuring methods were also accordance with that for microwave-vacuum.

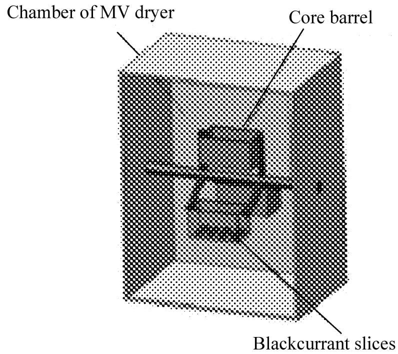


Fig. 1 Schematic of microwave-vacuum dryer diagram

1.4 Measurement of Volume and Expansion Ratio

The volume of blackcurrant slice can be measured by quartz sand replacement method. The concrete process was carried out as follow: a little of quartz sand was put into a measuring cylinder to cover the bottom of the cylinder, and then let 10 pieces of blackcurrant slice into the cylinder and put the quartz sand in the same time. Gently shake the cylinder until the gap filled solidly among slices, and the slices covered completely. The measured volume represented as the total volume of quartz sand and slices V_1, and then to take out the slices and determine the volume of quartz sand V_2. Finally, calculate the volume of slices according to

$$V = V_1 - V_2 \tag{1}$$

Expansion ratio was calculated as

$$P = \frac{V_t}{V_0} \times 100\% \tag{2}$$

where, P—expansion ratio of blackcurrant slice, %

V_0, V_t—initial volume and volume in t time, mL

1.5 Measurement of Moisture Content and Dehydration Rate

Moisture content of slice during the puffing process was calculated as

$$W_2 = W_1 \frac{1 - M_1}{1 - M_2} \tag{3}$$

where, M_1, M_2—moisture content of fresh blackcurrant slice before and after pretreatment in wet basis, %

W_1, W_2—mass of slice which before and after pretreatment, g

The dehydration rate of slice was described as

$$R_A = \frac{M_0' - M_t'}{t} \quad (4)$$

where, R_A—dehydration rate, %/s

t—total time of dehydration, s

M_0', M_t'—initial moisture content and moisture content in any time in dry basis, %

1.6 Measurement of Anthocyanin Content

The color value method was used to determine anthocyanin content of blackcurrant slice[1]. All experiments were replicated three times and the average values were considered as the finial results.

1.7 Profile Structure and Microstructure

Small sample (1 cm × 1 cm × 1 cm) was cut from the center of the blackcurrant slice, and then was put into scanning electron microscopy (Quanta 200; FEI Co., Ltd., Hillsboro, OR, USA) to perform microscopic observation under amplifying 800 times condition.

2 Results and Analysis

2.1 Effect of Different Puffing Methods on Expansion Ratio of Slice

Expansion ratio is an important index for puffing food. The higher the expansion ratio is, the greater the change of volume is. The change of expansion ratio during microwave or microwave-vacuum puffing process was shown as Fig. 2.

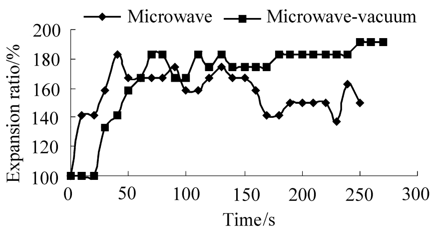
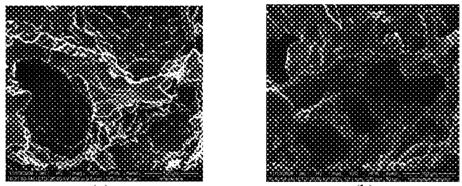


Fig. 2 Change of expansion ratio in different puffing methods

It is known from Fig. 2 that the expansion ratio of slice obtained by microwave method was higher than that by microwave-vacuum method up to 50 s, and thereafter became lower. At the first 10 s, the volume of slice was beginning to swell by microwave puffing and the expansion ratio was up to the maximum of 183.33% at the 40 s. Then the volume was slight shrinkage and the expansion ratio decreased by 33.33% when moisture content of slice reached 9.96%. While there was not obvious change for the volume of slice at the first 20 s and then was sharply swelled until 70 s time during microwave-vacuum process. Thereafter the expansion ratio was fluctuant and was up to the maximum of 191.67% in the end of puffing process. Compared with microwave puffing process, the volume was not shrinkage using microwave-vacuum puffing method in the late period. The reason is that the inner structure of slice for microwave puffing is easier to collapse than it using microwave-vacuum method during the solidified period due to the pressure subjected to slices is stronger at normal atmosphere during microwave puffing process than that in vacuum environment for microwave-vacuum method[18]. This result can be further certified by the photomicrograph that the microstructure of slice is looser and better layer for microwave-vacuum puffing than that for microwave puffing (shown as Fig. 3).



(a) (b)

Fig. 3 Slice's microstructure in different puffing methods
(a) Microwave puffing (b) Microwave-vacuum puffing

2.2 Effect of Different Puffing Methods on Moisture Change

2.2.1 Effect on Moisture Content

As can be seen from Fig. 4, both moisture contents of blackcurrant slice gradually decreased in the puffing process for microwave and microwave-vacuum method. In initial period of puffing, the moisture content by microwave method was slightly lower than that by microwave-vacuum method, while the difference of moisture content between these methods, was not significant after 150 s according to analysis of variance that the minimum of correlation coefficient was 0.140 9 and was more than 0.05 except for 250 s.

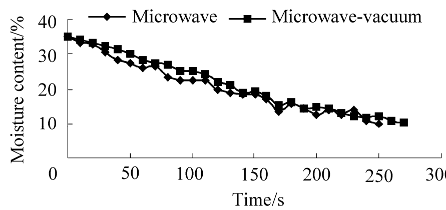


Fig. 4 Change of moisture content in different puffing methods

2.2.2 Effect on Dehydration Rate

It was shown in Fig. 5 that the puffing processes for both microwave and microwave-vacuum methods were in the accelerating dehydration stage at the first 10 s and the dehydration rates were up to the maximum. Thereafter, the dehydration rate decreased with the increasing of time for microwave puffing progress. While the dehydration rate was constant, and then decreased until the last 20 s for the microwave-vacuum process. Compared to microwave-vacuum puffing process, the dehydration rate of slice was higher and the evaporative water was more by microwave puffing method, which resulted in the less moisture content in initial period. While the dehydration rate decreased in the finial period, the moisture content for microwave method was similar with that for microwave-vacuum method.

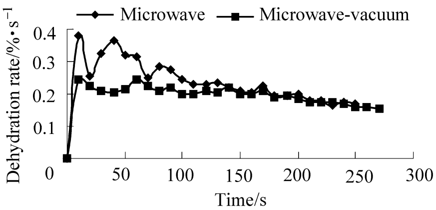


Fig. 5　Dehydration rate in different puffing methods

The difference of dehydration rate between microwave and microwave-vacuum puffing process is mainly relation with the change trend of volume and expansion ratio of blackcurrant slice. Compared to microwave-vacuum method, the volume of slice immediately swells in initial period of microwave puffing, and inner structure of slice is loose and porous that is beneficial to water transmission from the interior to exterior, and then evaporated through the surface, so the dehydration rate was fast and the moisture content was low. But with the continuation of puffing process, the volume of slice begins to shrinkage, and the inner porous structure collapses and compacts due to the atmospheric pressure is stronger by microwave method than the evaporation force, which prevents the water diffuse from interior to exterior, which results in the decrease of dehydration ratio. While for microwave-vacuum puffing process, the slice is in the vacuum environment and the pressure is low, and the inner structure is hard to collapse (Fig. 3b), so the dehydration rate can remain the constant.

2.3 Effect of Different Puffing Methods on Anthocyanin Content

Anthocyanin content for fresh blackcurrant is 350 mg/(100 g) and is about 8.8 times as many as the strawberry[19]. Due to the instability of the chemical property, the anthocyanin is easy to decompose during the food processing and storage.

Fig. 6 showed that the content of anthocyanin for fresh blackcurrant was highest in all samples and was up to (60.21 ± 0.31) mg/(100 g). While both anthocyanin contents of slices reduced for microwave and microwave-vacuum puffing technology. This indicated that the effects of these processes were passive on the anthocyanin. The anthocyanin content of slice by microwave puffing method was (35.71 ± 0.95) mg/(100 g) and decreased by 40.69% than that of fresh fruit, while the content by microwave-vacuum method was (55.75 ± 0.45) mg/(100 g) and reduced by 7.4%. Compared to microwave method, the anthocyanin content of blackcurrant slice increased 33.29% for microwave-vacuum technology.

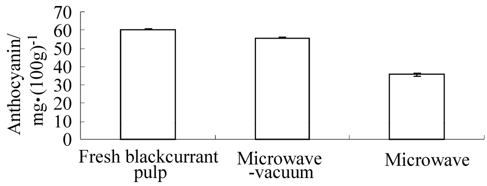


Fig. 6　Anthocyanin content in different puffing methods

This is primarily reason that high temperature and rich oxygen at the normal environment may result in the decomposition of anthocyanin in microwave puffing period. While for microwave puffing process, the slice swelled at the vacuum and closed environment. The slice is hard to contact with oxygen and the anthocyanin is not easy to be decomposed by oxidation reaction[8,20]. While the puffing process for microwave method was carried out in normal environment, the temperature is higher and oxygen is richer than that in vacuum condition. Therefore, the loss of anthocyanin for microwave puffing method is more than that for microwave-vacuum technology.

3 Conclusion

The expansion ratio of blackcurrant slice was first increased and then was in constant period, and the volume shrinkage did not occur for microwave-vacuum puffing method. For the dehydration rate, the puffing process by the microwave method was in the accelerating dehydration period at the first 10 s and was subsequently in the decelerating dehydration phase. While the puffing process was also in the accelerating dehydration period in first 10 s and then begun into the constant dehydration phase for microwave-vacuum method. The anthocyanin content of blackcurrant slice using the microwave-vacuum method was higher than that using the microwave method. Vacuum condition is advantage to improve the expansion ratio and the loss of anthocydanin in the microwave puffing process, but is not significant effect for the dehydration rate. Therefore, the microwave-vacuum puffing process was superior to microwave process for puffing characteristics of slice.

Reference

1 Zheng X Z, Liu C H, Zhou H, et al. Optimization of parameters for microwave-assisted foam mat drying of blackcurrant pulp [J]. Drying Technology, 2011, 29(2): 230 ~ 238.

2 Talcott S T. Berry fruit: value-added products for health promotion[M]. Taylor & Francis Group. LLC, 2007.

3 Slimestad R, Solheim H. Anthocyanins from black currants (*Ribes nigrum* L.) [J]. Journal of Agricultural and Food Chemistry, 2002, 50(11): 3 228 ~ 3 231.

4 Castillo M L R D, Dobson G, Brennan R, et al. Fatty acid content and juice characteristics in black currant (*Ribes nigrum* L.) genotypes[J]. Journal of Agricultural and Food Chemistry, 2004, 52(4): 948 ~ 952.

5 Hummer K E, Barney D L. Comprehensive crop reports-currants[J]. Hort Technology, 2002, 12(3): 377 ~ 387.

6 Seeram N P. Berry fruits: compositional elements, biochemical activities, and the impact of their intake on human health, performance, and disease[J]. Journal of Agricultural and Food Chemistry, 2008, 56(3): 627 ~ 629.

7 Mattila P H, Hellström J, McDougall G, et al. Polyphenol and vitamin C contents in European commercial blackcurrant juice products[J]. Food Chemistry, 2011, 127(3): 1 216 ~ 1 223.

8 Kongsoontornkijkul P, Ekwongsupasarn P, Chiewchan N, et al. Effects of drying methods and tea preparation temperature on the amount of vitamin C in Indian gooseberry tea[J]. Drying Technology, 2006, 24(11): 1 509 ~ 1 513.

9 Mori K, Goto-Yamamoto N, Kitayama M, et al. Loss of anthocyanins in red-wine grape under high temperature[J]. Journal of Experimental Botany, 2007, 58(8): 1 935 ~ 1 945.

10 Mottram D S, Wedzicha B L, Dodson A T. Food chemistry: acrylamide is formed in the Maillard reaction[J]. Nature, 2002, 419: 448 ~ 449.

11 Pitchai K. Electromagnetic and heat transfer modeling of microwave heating in domestic ovens[D]. Lincoln, NE: University of Nebraska-Lincoln, 2011.

12 Datta A K, Anantheswaran R C. Handbook of microwave technology for food applications[M]. Boca Raton, FL: CRC Press, 2001.

13 Liu C H, Zheng X Z, Shi J, et al. Optimising microwave-vacuum puffing for blue honeysuckle snacks[J]. International Journal of Food Science & Technology, 2010, 45(3): 506 ~ 511.

14 Han Q H, Li S J, Ma J W, et al. Analysis on energy consumption and product quality of microwave-vacuum drying and puffing apple slices[J]. Transactions of the Chinese Society for Agricultural Machinery, 2008, 39(1): 74 ~ 77. (in Chinese)

15 Ressing H, Ressing M, Durance T. Modeling the mechanisms of dough puffing during vacuum microwave drying using the finite element method[J]. Journal of Food Engineering, 2007, 82(4): 498 ~ 508.

16 Zhang J, Zhang M, Shan L, et al. Microwave-vacuum heating parameters for processing savory crisp bighead carp (*Hypophthalmichthys nobilis*) slices[J]. Journal of Food Engineering, 2007, 79(3): 885 ~ 891.

17 Mu Y Q, Liu C H, Zheng X Z, et al. Effects of microwave-vacuum puffing conditions on the texture characteristics and sensory properties of blackcurrant (*Ribes nigrum* L.) snack[J]. International Agricultural Engineering Journal, 2010, 19(3): 45 ~ 53.

18 Liu C H, Zheng X Z, Jia S H, et al. Comparative experiment on hot-air and microwave-vacuum drying and puffing of blue honeysuckle snack[J]. International Journal of Food Engineering, 2009, 5(4): 1 ~ 9.

19 Zhou H. Experimental studies on the microwave-assisted foam-mat drying of blackcurrant pulp[D]. Harbin: Northeast Agricultural University, 2009. (in Chinese)

20 Cheynier V, Souquet J M, Kontek A, et al. Anthocyanin degradation in oxidising grape musts[J]. Journal of the Science of Food and Agriculture, 1994, 66(3): 283 ~ 288.

微波与微波真空膨化黑加仑果片膨化特性对比

刘成海　郑先哲

（东北农业大学工程学院，哈尔滨 150030）

【摘要】 对微波或微波与真空相结合方式膨化黑加仑果片试验进行对比研究。在微波膨化过程中，微波强度为 20 W/g，黑加仑果片的初始含水率为 35%；而在微波真空膨化过程中，除真空压力不同，为 30 kPa 外，其他初始条件与微波膨化初始条件相同。试验结果表明：通过微波真空方式膨化得到的黑加仑果片，膨化率呈先增加，之后保持不变的趋势；在膨化过程的前 10 s，果片处于加速脱水阶段，此后进入恒速脱水阶段。而利用微波膨化得到的黑加仑果片，膨化率和脱水速率均呈先增加后减小的趋势。经过微波与真空相结合技术膨化处理后的黑加仑果片花青素保留率高于微波膨化处理。因此，微波与真空相结合技术获得的制品膨化特性优于常压下微波制品的膨化特性。

关键词： 黑加仑果片　微波真空　微波　膨化

中图分类号： TS255.36　**文献标识码：** A　**文章编号：** 1000-1298(2011)S0-0194-05