Influences of microwave vacuum puffing conditions on anthocyanin content of raspberry snack

Mu Yanqiu, Zhao Xinhuai, Liu Bingxin, Liu Chenghai, Zheng Xianzhe*

(*Northeast Agricultural University, Harbin, 150030, China*)

Abstract: Microwave technology is fit for the processing of berry products, but it may affect nutrition components of berry fruit. To improve the nutritional value of the berry products, the influences of microwave vacuum puffing conditions on the anthocyanin content of raspberry snack were investigated using central composite experiments. Results indicated that vacuum pressure had the most significant effect on the anthocyanins of berry snack, followed by the puffing time, microwave power, and initial moisture content. The interaction between microwave power and puffing time on the anthocyanins was extremely significant. Under microwave power of 2.68 kW and the puffing time of 81.00 s, the anthocyanin content of raspberry snack was retained at high level. The results can provide some technological basis for the berry fruit products processed with high quality.

Keywords: raspberry snack, microwave vacuum puffing, processing condition, anthocyanin content, absorbance

DOI: 10.3965/j.ijabe.20130603.0010

Citation: Mu Y Q, Zhao X H, Liu B X, Liu C H, Zheng X Z. Influences of microwave vacuum puffing conditions on anthocyanin content of raspberry snack. Int J Agric & Biol Eng, 2013; 6(3): 80－87.

1 Introduction

Raspberry (*Rubus idaeus*) is highly valuable berry fruit owing to its unique flavors, soft textures, and high nutrition. High contents of anthocyanins, vitamins and minerals in raspberry provide obvious health benefits[1,2]. Raspberry and its products had been accepted and favored by the consumers. However, raspberry has a short shelf life of 2-3 days at room temperature due to its succulence fruitage and thin pericarp. In addition to partial consumption of fresh fruit, the majority of harvested raspberries are frozen for the further processing. At present, raspberry products mainly include beverages, icecreams, jams and jellies. Raspberry snack puffed by microwave vacuum (MV) method is a novel leisure food with crisp-taste and rich nutrition.

The MV technology comes from the combination of rapid volumetric heating from microwave[3] and low drying temperature from vacuum environment, which is a potential method to process the fruit and vegetable[4]. Fruit and vegetable products based on MV processing method have high quality in terms of structure, volume and nutrient retention[5,6]. Lin et al.[7] reported that the carrot slices dried by MV had higher rehydration, higher α-carotene and vitamin C content, lower density, and softer texture than those dried by hot air. Liu et al.[8] suggested that blue honeysuckle slices puffed using MV method had higher quality attributes including hardness, crispness, color and vitamin C content than those using

Received date: 2013-04-21 **Accepted date:** 2013-07-22

Biographies: Mu Yanqiu, PhD, lecturer, majored in agricultural products processing, College of Science, and College of Food Science, Northeast Agricultural University, Email: muyanqiu@126.com; **Zhao Xinhuai,** PhD, professor, College of Food Science, Northeast Agricultural University, majored in food chemistry, Email: zhaoxh@mail.neau.edu.cn; **Liu Bingxin**, M.E candidate, College of Engineering, Northeast Agricultural University, majored in agricultural mechanization, Email: a07080583@126.com; **Liu Chenghai,** PhD, lecturer, College of Engineering, Northeast Agricultural University, majored in agricultural products processing, Email: lch_lch82@ yahoo.cn.

* **Corresponding author: Zheng Xianzhe,** PhD, professor, majored in agricultural products processing, College of Engineering, Northeast Agricultural University, Harbin 150030, China, Email: zhengxz@neau.edu.cn.

hot-air drying. Puffing phenomena with volume expansion and porous interior often occurred in products processed by MV method[9,10]. Microwave vacuum puffing (MVP) technology has been applied to process fruits and vegetables, such as apple, banana, carrot, mushroom, potato[11-17]. MVP processing may influence the quality of products in terms of structural characteristics, appearance, taste and nutrient component. Liu et al.[18] found the effect of MVP parameters including initial moisture content, vacuum pressure and microwave intensity on the quality attributes in terms of expansion ratio, hardness, crispness and color of blue honeysuckle snack. Mu et al.[19] studied that the influence of process conditions on the texture characteristic and sensory properties of berry snacks subjected to MV. Zheng et al.[20] presented the microwave power, vacuum degree and initial moisture content had significant influences on the dehydration and texture quality of raspberry snack and determined the volume expansion related to the dehydration rate of berry slab[21]. The loss of vitamin C and anthocyanins in berry product processed by MV is lower than that processed by the convective drying[22,23].

Anthocyanins are potent flavonoid antioxidants widely distributed in berry fruits, which provide health benefits and contribute antioxidant capacity. Processing conditions have effects on the stability of anthocyanins. However, little investigation was conducted on the influences of MV conditions on the anthocyanins of berry products. The objective of this study was to analyze the influences of MVP process parameters on the anthocyanin content of raspberry snack. The results would help to improve the quality of berry products.

2 Materials and methods

2.1 Materials and equipment

The fresh raspberries used in the experiment were supplied by Harbin Xinyue Three Berry Fruits Co. (Harbin, China) to frozen storage. The frozen raspberries were thawed at room temperature, then were cleaned and weighed. Soft sugar (Hongguang brand, Bocheng Sugar Co. Ltd, Nehe, China) was added to the raspberries at weight ratio of 1:5. The mixture of raspberry and sugar were crushed using an agitator (HR1727, Philips Domestic Appliance & Personal Care Co. of Zhuhai SEZ Ltd., Zhuhai, China) for 20 min for the preparation of raspberry puree. The moisture content of raspberry puree M_{re} (%, w.b.) was measured using direct drying method (GB5009.3-2010). The raspberry puree was concentrated and modulated to desired moisture content, M_P (%, w.b.) by MV dryer. During the modulation process of puree, the mass of evaporated water (Δm_w, g) satisfied Equation (1):

$$\Delta m_w = m_{re} - \frac{m_{re} \cdot (1 - M_{re})}{1 - M_p} \quad (1)$$

where, m_{re} is the mass of raw puree before concentrated process (g); M_{re} and M_p are the moisture contents of raw puree and concentrated puree (%, w.b.) respectively.

Raspberry leather consisted of concentrated puree and maltodextrin at solid ratio of 2:3. The additive amount of maltodextrin into concentrated berry puree was calculated as follows:

$$m_m = \frac{3m \cdot (1 - M_0)}{5(1 - M_m)} \quad (2)$$

where, m_m is additive amount of maltodextrin into concentrated berry puree (g); m and M_0 are the total mass (g) and the initial moisture content (%, w.b.) of berries slab respectively; M_m is the moisture content of maltodextrin with the value of (5.12±0.02)% (w.b.).

The desired moisture content of concentrated puree (M_P, %, w.b.) was given by:

$$M_P = \frac{m \cdot M_0 - m_m \cdot M_m}{m - m_m} \quad (3)$$

The moisture content of samples was measured using air drying oven. Uniform fruit leathers were cut with circular mold with the diameter of 24.50 mm and the thickness of 2.84 mm for preparation to MVP. Figure 1 showed the shapes of raw berry leather and puffed berry snack.

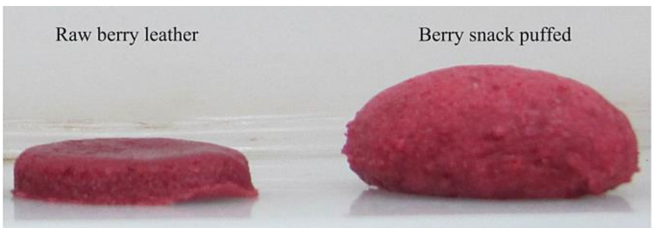


Figure 1 Raw berry leather and berry snack puffed

A MV dryer (QW-4HV, Guangzhou Kewei Microwave Energy Co. Ltd, Guangzhou, China) was used to puff raspberry slab. Dimensions of drying chamber (width × depth × height) were 800 mm × 900 mm × 1000 mm. Operations of MV puffing berry slab were conducted at three microwave output powers levels of 1.34 kW, 2.68 kW and 4.02 kW. Chamber pressure was set in the range of 0-90 kPa. There were six rotating baskets in the oven cavity.

2.2 Anthocyanin determination

Anthocyanins in raspberry snacks were measured by spectrophotometric method, and the procedure was as follows: (1) Preparation of chromogenic agent as follows: 100 mL vanillin methanol (1%) was added with 100 mL hydrochloric acid (8%). (2) About 2 g raspberry snacks was ground using a laboratory mill to powder and weighed, then added into 50 mL methanol. The mixed solution was oscillated for 30 min to dissolve fully, and filtrated, then diluted with methanol to 100 mL. One milliliter extracted solution was mixed to 5 mL chromogenic agent as the test solution. One milliliter methanol was added into 5 mL chromogenic agent as the blank solution. (3) The measurement of anthocynins of samples was carried out using an ultraviolet-visible spectrophotometer (6010-Type, Shanghai HP Analytical Instrument Co. Ltd, Shanghai, China) with the wavelength of 500 nm.

The anthocyanin absorbance, namely the equivalent of anthocyanin content, was measured. Absorbance was proportional to anthocyanin contents of raspberry snack[24], for example, higher absorbance value represented that berry snacks retained more anthocyanin component. The experiments were performed in triplicate, and the mean values were reported.

2.3 Experimental design

The five factors including microwave power, vacuum pressure, puffing time, initial moisture content and mass load were determined according to the results from preliminary experiments. Output powers of MV dryer were set at three levels of 1.34 kW, 2.68 kW and 4.02 kW. Thus, all factors were also determined at three levels to keep the level consistency of factors, and the level intervals were sufficient to cover the measure range. A second-order central composite design with five factors at three levels was used to determine the interactions of MVP parameters on the anthocyanin content of raspberry snack. The three levels of each factor were presented in Table 1.

Table 1 Factors and levels

Code	Microwave power *A*/kW	Vacuum pressure *B*/kPa	Puffing time *C*/s	Initial moisture content *D*/%, w.b.	Mass load *E*/g
-1	1.34	15	60	17	48
0	2.68	30	90	20	96
1	4.02	45	120	23	144

2.4 Statistical analysis

Experimental data were statistically analyzed by regression and analyses of variance (ANOVA) using the Design Expert software (Version 6.0.10, Stat-Ease, Inc, Minneapolis, MN, USA).

3 Results and discussion

Fifty groups of experiments were performed, and anthocyanin absorbances (the equivalent of anthocyanin content) under different MV parameter combinations were presented in Table 2.

Analyses of variance (ANOVA) were carried out to investigate the statistical significance of independent variables on the equivalent of anthocyanin content of the snack as shown in Table 3.

As shown in Table 3, F value of the model was 6.03 ($P < 0.0001$), and the model was extremely significant. B, C and AC ($P < 0.01$) were extremely significant model terms. A, D, and AE interactions were significant model terms ($P < 0.05$). Lack of Fit ($F = 0.66$, $P > 0.1$) was insignificant, and it implied that the data were in good agreement with the model within the ranges of experiments. The coefficient of determination ($R^2 = 0.8061$) indicated that the model could explain the response of 80.6%. The insignificant factors were eliminated from the model, and the quadratic regression model for the anthocyanin absorbance was shown in Equation (4).

$$Y = 0.36857 + 0.069397A - 2.28150\times10^{-4}B + 2.13755\times10^{-3}C - 0.043921D - 4.41017\times10^{-4}AC + 1.07661\times10^{-4}AE \quad (4)$$

Table 2 Experimental scheme and results

No.	Microwave power *A*/kW	Vacuum pressure *B*/kPa	Puffing time *C*/s	Initial moisture content *D*/%, w.b.	Mass *E*/g	Absorbance *Y*
1	1.34	15	60	17	48	0.043
2	4.02	15	60	17	48	0.046
3	1.34	45	60	17	48	0.035
4	4.02	45	60	17	48	0.041
5	1.34	15	60	17	144	0.045
6	4.02	15	60	17	144	0.059
7	1.34	45	60	17	144	0.018
8	4.02	45	60	17	144	0.046
9	2.68	30	90	17	96	0.054
10	1.34	15	120	17	48	0.060
11	4.02	15	120	17	48	0.024
12	1.34	45	120	17	48	0.032
13	4.02	45	120	17	48	0.007
14	1.34	15	120	17	144	0.044
15	4.02	15	120	17	144	0.018
16	1.34	45	120	17	144	0.030
17	4.02	45	120	17	144	0.015
18	2.68	30	60	20	96	0.038
19	2.68	30	90	20	48	0.029
20	2.68	15	90	20	96	0.037
21	1.34	30	90	20	96	0.041
22	2.68	30	90	20	96	0.028
23	2.68	30	90	20	96	0.038
24	2.68	30	90	20	96	0.050
25	2.68	30	90	20	96	0.051
26	2.68	30	90	20	96	0.057
27	2.68	30	90	20	96	0.032
28	2.68	30	90	20	96	0.043
29	2.68	30	90	20	96	0.044
30	4.02	30	90	20	96	0.025
31	2.68	45	90	20	96	0.042
32	2.68	30	90	20	144	0.057
33	2.68	30	120	20	96	0.029
34	1.34	15	60	23	48	0.047
35	4.02	15	60	23	48	0.046
36	1.34	45	60	23	48	0.017
37	4.02	45	60	23	48	0.028
38	1.34	15	60	23	144	0.019
39	4.02	15	60	23	144	0.060
40	1.34	45	60	23	144	0.018
41	4.02	45	60	23	144	0.036
42	2.68	30	90	23	96	0.049
43	1.34	15	120	23	48	0.059
44	4.02	15	120	23	48	0.010
45	1.34	45	120	23	48	0.025
46	4.02	45	120	23	48	0.009
47	1.34	15	120	23	144	0.038
48	4.02	15	120	23	144	0.015
49	1.34	45	120	23	144	0.028
50	4.02	45	120	23	144	0.011

Table 3 Regression and variance analysis of Absorbance *Y*

Source	Sum of Squares	DF	Mean Square	*F* Value	*P* > *F*
Model	8.850E-03	20	4.425E-04	6.03	<0.0001**
A	3.222E-04	1	3.222E-04	4.39	0.0450*
B	1.601E-03	1	1.601E-03	21.82	<0.0001**
C	1.043E-03	1	1.043E-03	14.22	0.0007**
D	3.202E-04	1	3.202E-04	4.36	0.0456*
E	2.092E-07	1	2.092E-07	2.85E-03	0.9578
A^2	2.043E-04	1	2.043E-04	2.78	0.1060
B^2	1.878E-05	1	1.878E-05	0.26	0.6168
C^2	1.825E-04	1	1.825E-04	2.49	0.1257
D^2	2.191E-04	1	2.191E-04	2.99	0.0947
E^2	8.259E-07	1	8.259E-07	0.011	0.9162
AB	1.389E-04	1	1.389E-04	1.89	0.1794
AC	3.321E-03	1	3.321E-03	45.26	<0.0001**
AD	8.681E-06	1	8.681E-06	0.12	0.7334
AE	5.067E-04	1	5.067E-04	6.90	0.0136*
BC	6.722E-06	1	6.722E-06	0.09	0.7643
BD	1.389E-06	1	1.389E-06	0.02	0.8915
BE	6.422E-05	1	6.422E-05	0.88	0.3573
CD	2.335E-05	1	2.335E-05	0.32	0.5771
CE	1.701E-05	1	1.701E-05	0.23	0.6338
DE	1.250E-07	1	1.250E-07	1.70E-03	0.9674
Residual	2.128E-03	29	7.338E-05		
Lack of fit	1.433E-03	22	6.516E-05	0.66	0.7887
Pure error	6.947E-04	7	9.924E-05		
Cor total	1.098E-02	49			

Note: **extremely significant ($P < 0.01$), *significant ($P < 0.05$).

According to the *F* value of model terms, the sequence of the factors affecting the anthocyanin content from high to low was vacuum pressure, puffing time, microwave power, initial moisture content and mass load.

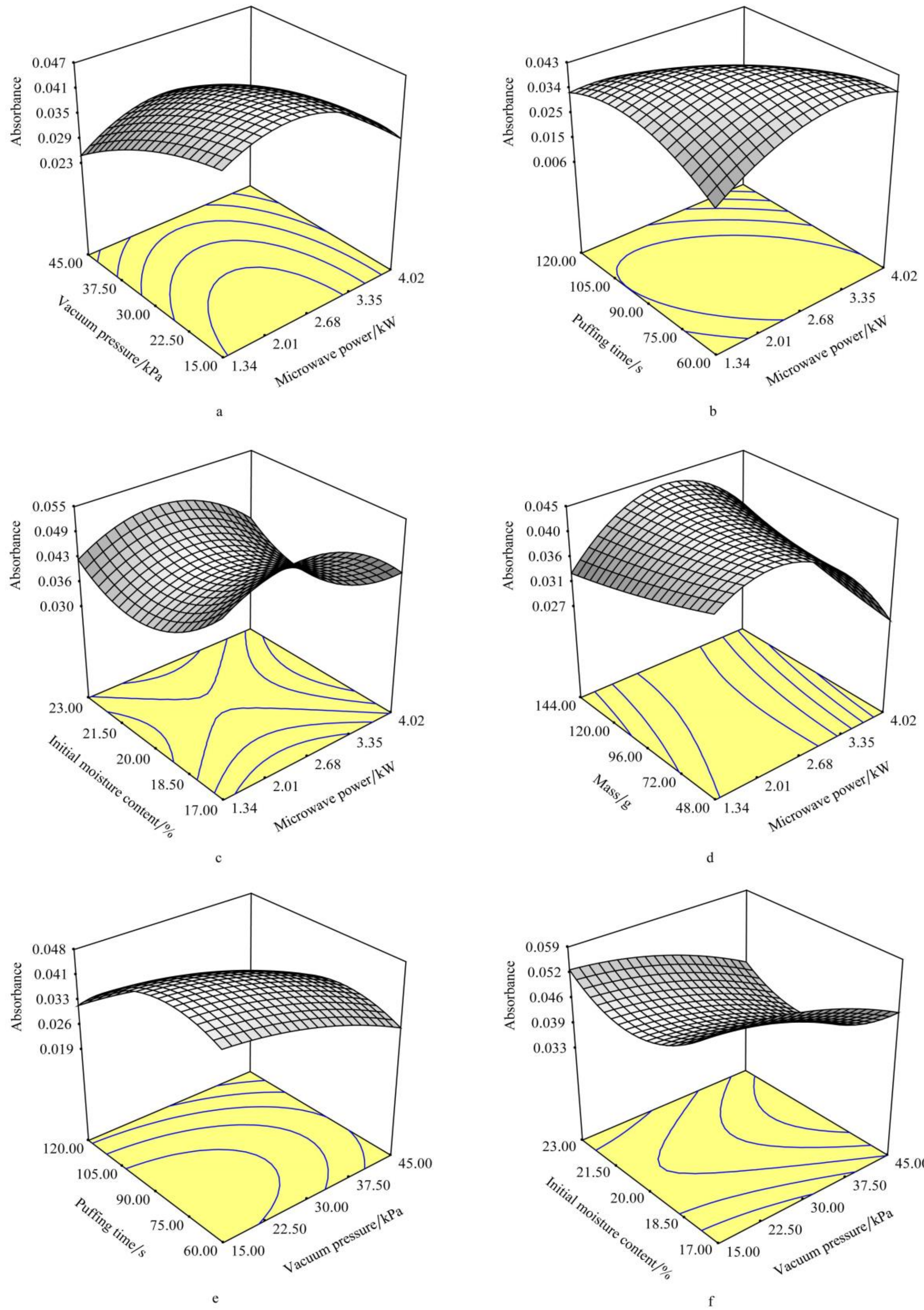
Figure 2 shows the response surface plots of the interaction between every two parameters on the absorbance under the center point level of other factors. As the heat- and oxygen- sensitive component, the degradation degree of anthocyanins in berry snack depends on the heating time, temperature, moisture content and oxygen content in the vacuum oven.

3.1 Effect of microwave power on the anthocyanin content of berry snack

As shown in Figure 2 (a, c, d), the vacuum pressure, initial moisture content and mass load were held at a certain level, the absorbance initially increased and then decreased with the increase of microwave power. When the microwave power was in the range of 2.15-2.68 kW, the absorbance was relatively high (0.045-0.055). High microwave power caused the rising temperature of snack to degrade its anthocyanins. The moisture content of berry snack was higher under lower microwave power, which resulted in the decomposition of the anthocyanin component[25].

3.2 Effect of vacuum pressure on the anthocyanin content of berry snack

Vacuum pressure had an extremely significant effect on the absorbance, but the interaction between vacuum pressure and the other factors was insignificant (shown in Table 2). While the other process parameters were fixed, the absorbance had a negative correlation with vacuum pressure, as shown in Figure 2 (a, e, f, g). Anthocyanins was easily degraded in oxygen-enriched environments, therefore anthocyanin loss within snacks was reduced at lower vacuum pressure value under MVP conditions.



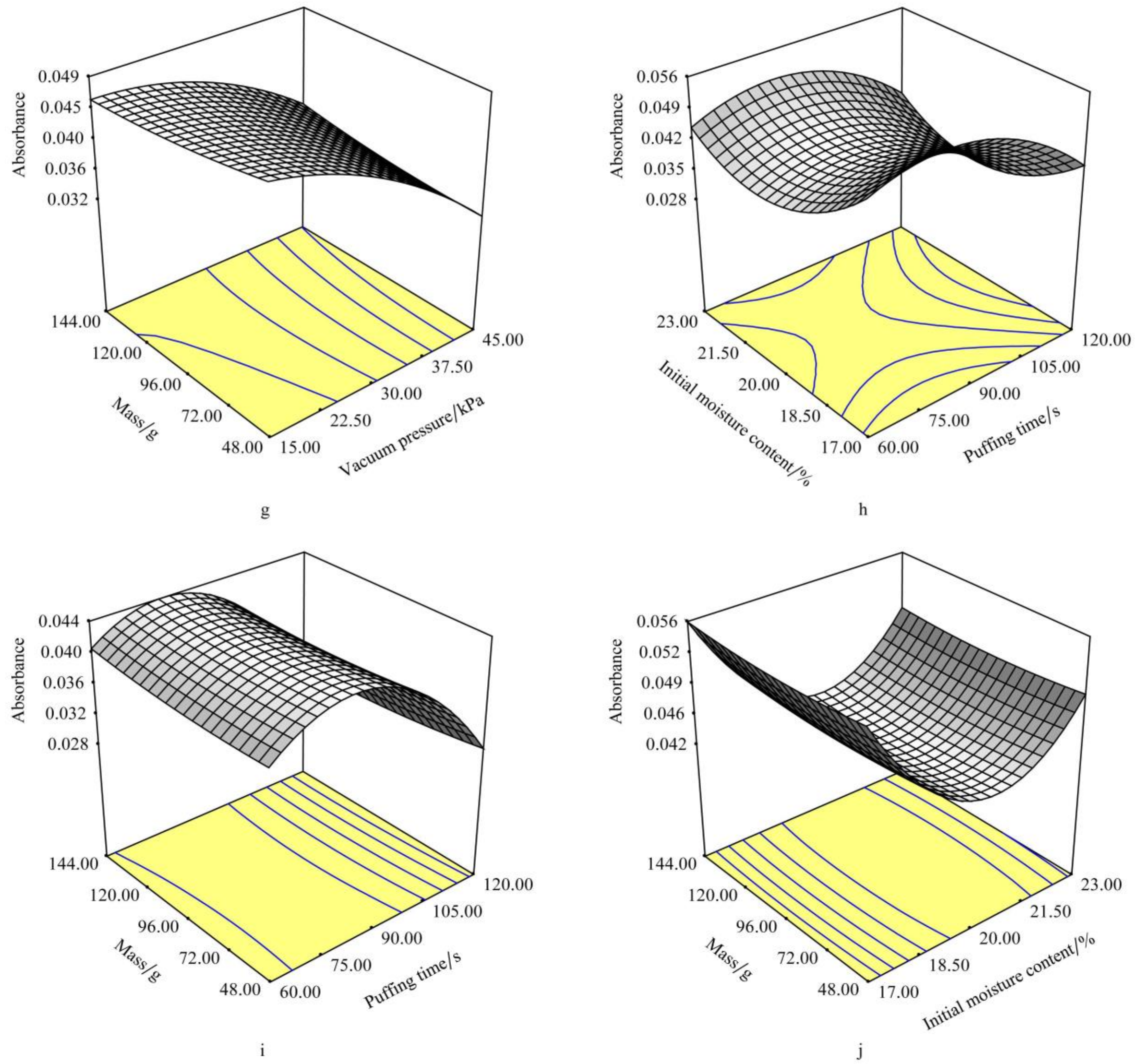


Figure 2 Response surface plot of the effect of process parameters on the absorbance

3.3 Effect of puffing time on the anthocyanin content of berry snack

Figure 2 (e, h, i) revealed that the absorbance was firstly increased and then decreased with the increase of puffing time. The anthocyanin content of snack was the maximum at puffing time of 80.00 s. This result may explain that anthocyanin concentration increases inside berry leather with the decrease of moisture content at the beginning stage of MVP, then the higher temperature in snack may result in the degradation of anthocyanins at the later stage.

3.4 Effect of initial moisture content on the anthocyanin content of berry snack

Results in Table 3 indicated the effect of initial moisture content on the absorbance was significant, but the interactions between initial moisture content and other factors were insignificant. As Figure 2 (c, f, h, j) shown, the absorbance initially decreased and then increased with the increase of initial moisture content of raspberry leather. At initial moisture of 20.6% (w.b.), the anthocyanin content reached the lower level.

3.5 Effect of mass load on the anthocyanin content of berry snack

Effect of mass load on the absorbance was insignificant (P = 0.9578>0.1). By means of the whole analysis of Figure 2 (g, i, j), it could be noticed that the variation of absorbance with mass load was slight, but the interaction between mass load and microwave power was significant (shown in Table 3).

3.6 Interaction between process parameters on the anthocyanin content of berry snack

The interaction between microwave power and puffing time on the absorbance was extremely significant (P < 0.01) as shown in Figure 2b. In short puffing time (60 s), the absorbance increased firstly and then decreased with the increase of microwave power. On the contrary, the increase of microwave power resulted in the absorbance increased under the long puffing time (120 s). Under microwave power of 1.34 kW, the absorbance increased with the increase of puffing time from 60.00 s to 81.00 s, whereas the absorbance values decreased slightly when the puffing time exceeded 81.00 s under the microwave power of 4.02 kW. In the observed range, the high value of the absorbance (0.043) was obtained at the microwave power of 2.68 kW and the puffing time of 81.43 s.

The influence of microwave power and mass load on the absorbance was significant (F=6.90, P = 0.0136<0.05) (shown in Figure 2d). When the mass load was fixed a constant, the absorbance firstly increased and then deceased with microwave power. Under the low microwave power of 1.34 kW, the negative effect of mass load on the absorbance was observed. On the contrary, the absorbance was positively correlated with the mass load in the condition of high microwave power (4.02 kW). For high power and low mass load, the high value of microwave intensity (ratio of microwave power to mass load) caused the degradation of anthocyanins inside berry snacks. The highest value of absorbance was obtained under the mass load of 48 g and the microwave power of 2.15 kW. Appropriate microwave intensity may reduce the anthocyanin loss inside berry products.

4 Conclusions

The effects of MVP conditions on anthocyanin content of raspberry snack were investigated in this study. Vacuum pressure has the most significant effect on the anthocyanins of berry snack. Oxygen loss in vacuum environment contributes to the stability of anthocyanin component inside berry slab. The effect of puffing time is extremely significant, and appropriate puffing time may improve the anthocyanin content of the raspberry snack. The effects of microwave power, as well as initial moisture content on the anthocyanins are remarkable. When the microwave power ranged from 2.15 kW to 2.68 kW, the high anthocyanin remained was measured in the experiments. When initial moisture content of raspberry slab was 20.6% (w.b.), the anthocyanin of snack was the lowest. The interaction between microwave power and puffing time on the anthocyanins is extremely significant. When the microwave power and the puffing time were applied at 2.68 kW and 81.00 s, respectively, the high anthocyanin equivalent value was obtained in the experimental range. The interaction between microwave power and mass load on the anthocyanins was significant. The appropriate power was set according to mass load to reduce the anthocyanin loss.

Acknowledgments

The authors thank the financial support by the National Natural Science Foundation of China (No. 31071579 & 31271911), the Key Program of the Natural Science Foundation of Heilongjiang Province of China (No. ZD201013) and Key Project of Education Department of Heilongjiang Province of China (No. 12521z003) for this research project.

[References]

[1] Pantelidis G E, Vasilakakis M, Manganaris G A, Diamantidis Gr. Antioxidant capacity, phenol, anthocyanin and ascorbic acid contents in raspberries, blackberries, red currants, gooseberries and Cornelian cherries. Food Chemistry, 2007; 102(3): 777-783.

[2] God J, Tate P L, Larcom L L. Red raspberries have antioxidant effects that play a minor role in the killing of stomach and colon cancer cells. Nutrition Research, 2010; 30(11): 777-782.

[3] Zheng X Z, Wang Y K, Liu C H, Sun J K, Liu B X, Zhang B H, et al. Microwave energy absorption behavior of foamed berry puree under microwave drying conditions. Drying Technology, 2013; 31(7): 785-794.

[4] Drouzas A E, Schubert H. Microwave Application in vacuum drying of Fruits. Journal of Food Engineering, 1996; 28(2): 203-209.

[5] Erle U, Schubert H. Combined osmotic and microwave-vacuum dehydration of apple and strawberries. Journal of Food Engineering, 2001; 49(2-3): 193-199.

[6] Giri S K, Prasad S. Drying kinetics and rehydration characteristics of microwave-vacuum and convective hot-air dried mushrooms. Journal of Food Engineering, 2007(2);

78: 512-521.

[7] Lin, T M, Durance T D, Scaman C H. Characterization of vacuum microwave, air and freeze dried carrot slices. Food Research International, 1998; 31(2): 111-117.

[8] Liu C H, Zheng X Z, Jia S H, Ding N Y, Gao X C. Comparative experiment on hot-air and microwave-vacuum drying and puffing of blue honeysuckle snack. International Journal of Food Engineering, 2009; 5(4): 1-9.

[9] Li Y Z, Zheng S X, Luo S C, Fei K, Chen D X. Study on the processing characteristics of potato crispy chips by vacuum microwave. Food and Fermentation Industries, 2003; 29(8): 40-43.

[10] Han Q H, Li S J, Ma J W, Zhao D L. Microwave vacuum drying and puffing characteristics of apple chips. Transactions of the Chinese Society for Agricultural Machinery, 2006; 37(8): 155-158.

[11] Mousa N, Farid M. Microwave Vacuum Drying of Banana Slices. Drying Technology, 2002; 20(10): 2055-2066.

[12] Contreras C, Martin M E, Mart ńez-Navarrete N, Chiralt A. Effect of vacuum impregnation and microwave application on structuralchanges which occurred during air-drying of apple. LWT-Food Science and Technology, 2005; 38(5): 471-477.

[13] Giri S K, Prasad S. Modeling shrinkage and density changes during microwave-vacuum drying of button mushroom. International Journal of Food Properties, 2006; 9(3): 409-419.

[14] Giri S K, Prasad S. Optimization of microwave-vacuum drying of button mushrooms using response-surface methodology. Drying Technology, 2007; 25(5): 901-911.

[15] Stepień B. Effect of vacuum-microwave drying on selected mechanical and rheological properties of carrot. Biosystems Engineering, 2008; 99(2): 234-238.

[16] Bondaruk J, Markowski M, Blaszczak W. Effect of drying conditions on the quality of vacuum-microwave dried potato cubes. Journal of Food Engineering, 2007; 81(2): 306-312.

[17] Song X J, Zhang M, Mujumdar A S, Fan L P. Drying characteristics and kinetics of vacuum microwave-dried potato slices. Drying Technology, 2009; 27(9): 969-974.

[18] Liu C H, Zheng X Z, Shi J, Xue J, Lan Y B, Jia S H. Optimising microwave vacuum puffing for blue honeysuckle snacks. International Journal of Food Science and Technology, 2010; 45(3): 506-511.

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

[20] Zheng X Z, Liu C H, Mu Y Q, Liu H J, Song X Y, Lin Z, et al. Analysis of puffing characteristics using a sigmodal function for the berry fruit snack subjected to microwave vacuum conditions. Drying Technology, 2012; 30(5): 494-504.

[21] Zheng X Z, Liu C H, Shi J, Xue S, Mu Y Q, Lin Z, et al. Analysis of volume expansion and dehydration rate of berry slab under microwave-vacuum puffing conditions. LWT-Food Science and Technology, 2013; 52(1): 39-48.

[22] Vaghri Z, Scaman Ch H, Kitts D D, Durance T D, McArthur D A J. Quality of the vacuum microwave dried blueberries in terms of color, composition, and antioxidant activity. In: Proceedings of the 12th International Drying Symposiums-IDS. Elsevier Science: Amsterdam, The Netherlands, 2000; paper 318, pp. 1-10.

[23] Wojdyło A, Figiel A, Oszmiański J. Effect of drying methods with the application of vacuum microwaves on the bioactive compounds, color, and antioxidant activity of strawberry fruits. Journal of Agricultural and Food Chemistry, 2009; 57(4): 1337-1343.

[24] Zheng X Z, Xu X W, Liu C H, Sun Y, Lin Z, Liu H J. Extraction characteristics and optimal parameters of anthocyanin from blueberry powder under microwave-assisted extraction conditions. Separation and Purification Technology, 2013; 104: 17-25.

[25] Lohachoompol V, Srzednicki G, Craske J. The change of total anthocyanins in blueberries and their antioxidant effect after drying and freezing. Journal of Biomedicine and Biotechnology, 2004; 2004(5): 248-252.