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Study on Pre-Treatment Technology of Sucrose Impregnation of Blackened Hawthorn

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Abstract. The traditional hawthorn product market is shrinking year by year, and there is a serious contradiction between supply and demand. The blackening reaction can not only change the original quality of hawthorn, but also provide a new way for hawthorn processing. In this paper, hawthorn was used as raw material, processed by blackening technology, and sensory evaluation is used as an index to optimize the process of sugar liquid immersion pre-treatment by single factor experiment and response surface methodology. The results showed that the optimal process parameters: sucrose concentration of 60%, immersion time of 32h, solid-liquid ratio of 1:2.3, and immersion temperature of 38℃. Under this condition, the sensory score of blackened hawthorns was 98.14±0.03. The blackened hawthorn produced by this process had uniform colour, moderate hardness, strong chewiness.

Keywords: Blackened hawthorn; pre-treatment; sucrose impregnation; process optimization.

1. Introduction

Hawthorn is widely distributed in northern China. In recent years, with the adjustment of the industrial structure, the planting area of hawthorn in my country has grown rapidly, and the output of hawthorn has grown rapidly [1]. The traditional processed products are relatively simple, and the added value of the products is not high. Therefore, it is necessary to explore and develop a new type of hawthorn processed products, which can not only improve the depth and precision of hawthorn processing, but also enable the nutritional value and economic value of hawthorn to be obtained.

Blackened technology is an emerging processing in recent years [2]. It refers to a fruit and vegetable processing technology that puts them under the condition of high temperature and high humidity, a series of physical and chemical reactions occur themselves, and the colour changes to black or brown [3]. After blackening, the sensory quality of fruits and vegetables will be changed, which has a profound influence on the flavour and taste of fruits and vegetables [4].

Pre-treatment of fruits and vegetables can make better contact between cells or cell components, speed up the processing rate, and improve product quality. The commonly used processing and pre-treatment methods of fruits and vegetables include physical methods, chemical methods, and biological methods. Among them, thermal treatment can improve the water movement rate in the cell wall of plants [5]. Changes in the cell wall of plants can promote their permeability, reduce mass transfer resistance, and improve processing efficiency. In the process of fruit and vegetable blackening, the key to the change of flavour, nutrition and function is the Maillard reaction between the sugars contained in the fruit and vegetable itself and free amino groups [6]. The influence of amino acid types on the Maillard reaction rate mainly depends on the position of the amino group and the length of the carbon chain, while the influence of sugar types on the reaction rate mainly depends on the type of sugar. Therefore, based on the research in this laboratory, the process of sucrose impregnation was optimized to find the best process.

2. Materials and Method

2.1 Plant Material

Hawthorn is provided by Shandong Wanbang Food Co., Ltd. And stored in a cool and dry place.The hawthorn with seedless was first blanched in water of 95°C for 1.5 min, then soaked in a solution of sucrose, and then bagged and processed in oven with temperature of 80°C for about 9 days to produce blackened hawthorn.

2.2 Single-Factor Experiment

Sensory evaluation was used as an indicator, controlling its three factors to remain unchanged, changing one factor, studying sucrose concentrations (20%, 30%, 40%, 50%, 60%), immersion time (8 h, 16 h, 24 h, 32 h, 40 h), solid-liquid ratio (1:1 kg/L, 1:1.5 kg/L, 1:2 kg/L, 1:2.5 kg/L, 1:3 kg/L), immersion temperature (20℃, 25℃, 30℃, 35℃, 40℃) on sensory evaluation of blackened hawthorn.

2.3 Response Surface Optimization Experiment

On the basis of the single factor experiment, mathematical model between each factor and its interaction and sensory evaluation was established to study the sucrose concentration (A), immersion time (B), solid-liquid ratio (C) and immersion temperature (D) and their interaction effects on the sensory evaluation of blackened hawthorn, the factors and level codes are shown in the table 1.

Table 1. Factors and level table of RSM.

Level	A Sugar concentration (%)	B Impregnation time (h)	C Solid-liquid ratio	D Impregnation temperature (℃)
-1	40	16	1:1.5	30
0	50	24	1:2	35
1	60	32	1:2.5	40

2.4 Sensory Evaluation

The sensory evaluation was modified with reference to the method of Karnjanapratum [7]. Each group member evaluated the aroma, colour, taste, and texture of the samples by the following scoring methods. The specific scoring methods are shown in table 2.

Table 2. Sensory evaluation standard of black hawthorn.

Sensory indicators (points)	Evaluation standard	Score
Color (20)	Dark brown, uniform color	15-20
	Dark brown, different color	8-15
	Yellowish-brown, very different in color	0-8
Texture (30)	Moderate hardness, elasticity, non-stick	25-30
	Hardness is soft, inelastic, basically non-stick to the teeth	15-24
	Hardness is very soft or too hard, inelastic, stick to the teeth	0-14
Taste (30)	Strong chewiness, moderate sourness, no bitterness	25-30
	Not chewy, slightly sour, slightly bitter	15-24
	No chewiness, sour taste, severe bitterness	0-14
Aroma (20)	Blackened hawthorn has a strong smell and no peculiar smell	15-20
	Blackened hawthorn has a strong smell, with some peculiar smells	8-15
	No blackened hawthorn smell, bed smell	0-8

2.5 The Data Analysis

During the experiment, each experiment was performed in parallel three times. SPSS 26.0, Excel 2020, Minitab 19 and other software were used for experimental design and data analysis. The mean ± standard deviation represents the experimental results.

3. Results and Discussions

3.1. The Effect of Different Sucrose Concentration on Hawthorn

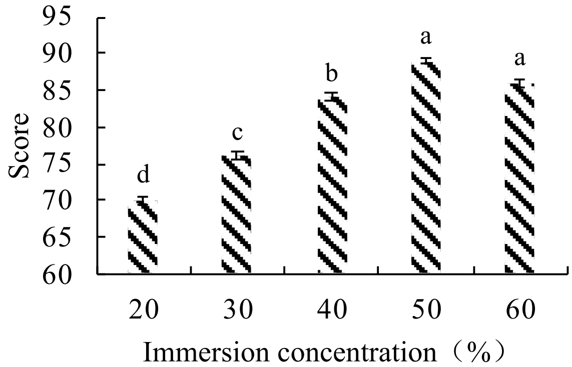

Figure 1. Effect of different sucrose concentrations on sensory evaluation of black hawthorn.

It can be seen from figure 1 that when the sucrose concentration is less than 50%, the sensory score of blackened hawthorn increases with the increase of the sugar concentration, and when the sucrose concentration is 50%, the sensory score reaches the maximum.

3.2. Effects of Different Sucrose Immersion Time on Blackened Hawthorn

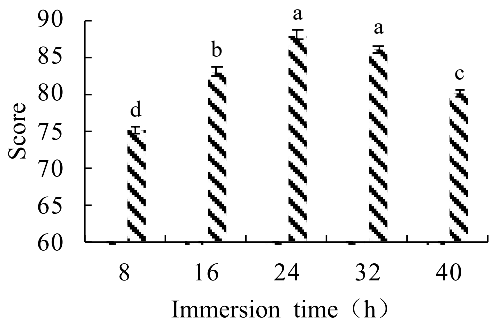

Figure 2. Effect of different time of Sucrose Immersion on sensory evaluation of black hawthorn.

Figure 2 shows that the sensory score increases significantly with the immersion time in the range of 8 to 24 h ($P<0.05$). When the immersion time is 24 h, the sensory score is the highest. When the immersion time exceeds 24 h, the sensory score increases significantly. Therefore, the optimal immersion time was determined to be 24 h.

3.3. Effects of Different Sucrose Dipping Solid-Liquid Ratios on Blackened Hawthorn

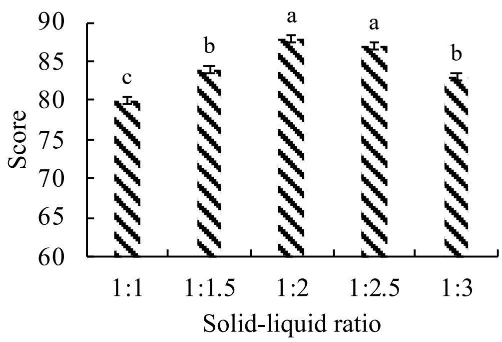

Figure 3. Effect of different solid-liquid ratio on sensory evaluation of black hawthorn.

It can be seen from figure 3 that with the gradual increase of the solid-liquid ratio, the sensory evaluation of blackened hawthorn showed a significant upward trend (P<0.05) and reached the maximum when the solid-liquid ratio was 1:2. When the ratio of solid to liquid is 1:2, it reaches the maximum. When the ratio of solid to liquid is greater than 1:2, the sensory score decreases slightly (P>0.05), and the ratio of solid to liquid is 1:2 for the next experiment.

3.4. Effects of Different Sucrose Immersion Temperatures on Blackened Hawthorn

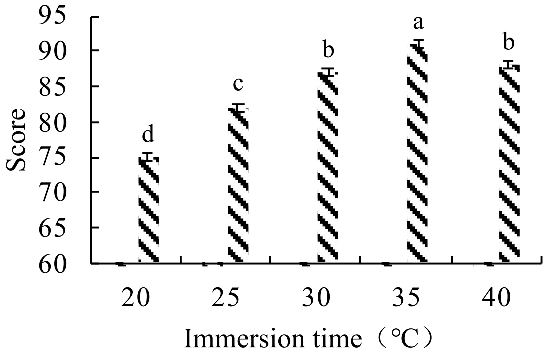

Figure 4. Effect of different temperature of sucorse immersion on sensory evaluation of black hawthorn.

As can be seen from figure 4, with the increase of immersion temperature, the sensory score of blackened hawthorns showed a trend of first increase and then decrease, reaching the maximum when the immersion temperature was 35 °C, and as the immersion temperature continued to increase, the sensory score decreased (P<0.05), therefore, the optimal immersion temperature was 35 °C.

3.5. Response Surface Optimization

The Box-Behnken experimental design and results are shown in table 3, and the variance analysis of the regression model is shown in table 4.

Table 3. Results of RSM experiment.

Run	A Sucrose concentration (%)	B Impregnation time (h)	C Solid-liquid ratio	D Impregnation temperature (℃)	Score
1	-1 (40)	0 (24)	1 (1：2.5)	0 (35)	81
2	-1	1 (32)	0 (1：2)	0	91
3	1 (60)	0	-1 (1：1.5)	0	90
4	-1	0	0	-1 (30)	85
5	1	0	1	0	88
6	0 (50)	1	0	-1	92
7	0	-1 (16)	-1	0	80
8	0	1	-1	0	92
9	0	0	0	0	93
10	0	-1	0	1 (40)	78
11	0	1	0	1	90
12	1	1	0	0	98
13	0	0	1	-1	78
14	0	-1	1	0	75
15	-1	0	0	1	76
16	-1	-1	0	0	79
17	-1	0	-1	0	77
18	0	0	1	1	80
19	0	1	1	0	81

20	0	0	0	0	92
21	0	0	-1	1	86
22	1	-1	0	0	91
23	1	0	0	1	94
24	1	0	0	-1	89
25	0	-1	0	-1	89
26	0	0	-1	-1	88
27	0	0	0	0	91

Table 4. ANOVA of RSM for the yield of flavonoids.

Source	Sum of squares	df	Mean square	F value	P-value (Prob>F)
Model	994.77	14	71.055	8.11	< 0.0001
A	310.08	1	310.083	35.41	< 0.0001
B	225.33	1	225.333	25.73	< 0.0001
C	75.00	1	75.000	8.56	0.013
D	24.08	1	24.083	2.75	0.123
AB	6.25	1	6.250	0.71	0.415
AC	9.00	1	9.000	1.03	0.331
AD	49.00	1	49.000	5.60	0.036
BC	9.00	1	9.000	1.03	0.331
BD	20.25	1	20.250	2.31	0.154
CD	4.00	1	4.000	0.46	0.512
A_2	11.34	1	11.343	1.30	0.277
B_2	17.93	1	17.926	2.05	0.178
C_2	249.04	1	249.037	28.44	0.000
D_2	54.90	1	54.898	6.27	0.028
Residual	103.08	10	10.308	10.31	0.092
Lack of fit	2.00	2	1.000		

According to table 3, the software Minitab 17.01 was used to analyze the experimental results. The dependent variable was the sensory score, and the independent variables were the concentration of A sugar solution, B immersion time, C solid-liquid ratio and D immersion temperature. A quadratic response surface model was established, and the obtained the equation is:

Y (sensory score) =92.00+5.083A+4.333B-2.500C-1.417D-1.46A2-1.83B2-6.83C2+3.21D2-1.25AB-1.50AC+3.50AD-1.50BC+2.25BD+ 1.00CD

By performing variance analysis on the regression equation obtained, the results are shown in table 4. From the data analysis in Table 4, the model P value is <0.0001, and the correlation coefficient (R2) = 0.9538. It shows that the regression model has a high degree of fit and can better predict the actual value of the index within the research range of each factor. According to the data analysis, the influence of dipping factors on the sensory score of blackened hawthorns is: A sugar solution concentration>B dipping time>C material-liquid ratio>D dipping temperature. Among them, the P values of factors A and B are all <0.01, indicating that the influence is extremely significant; the P value of factor C is <0.05 and >0.01, indicating that the impact is significant, and the P value of factor D is >0.05, indicating that the impact is not significant; the quadratic term C2 The P value of AB, AC, BC, BD, CD, A2, B2 with P value >0.05 indicates that the effect is not significant.

The optimal sugar solution dipping process obtained by the optimizer is: sugar solution concentration 60%, dipping time 32 h, material-liquid ratio 0.5354, dipping temperature 38.08℃, under these conditions, the theoretical value of sensory score is 99.20. According to the operability of the experiment, the experimental conditions were adjusted as follows: the concentration of sugar solution was 60%, the immersion time was 32 h, the ratio of material to liquid was 1:2.3, and the immersion temperature was 38 °C. Three verification experiments were carried out, and the sensory score was 98.14±0.03, which was close to the predicted value, indicating that the model had high reliability and could better predict the process.

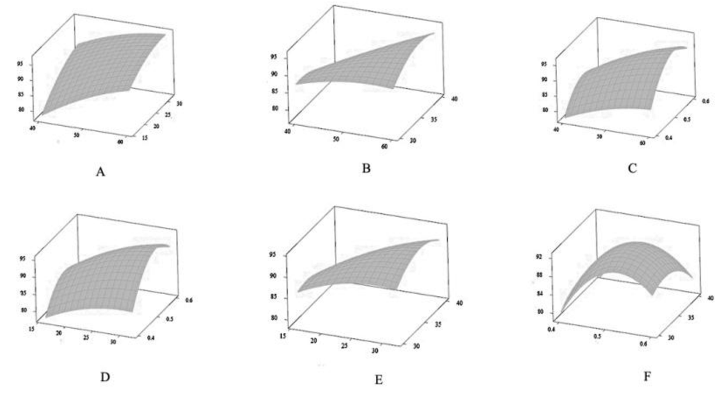

Figure 5. Response surface plots.

(A) Interaction of sucrose concentration and immersion time (B) Interaction of sucrose concentration and solid-liquid ratio (C) Interaction of sucrose concentration and immersion temperature (D) Interaction of immersion time and solid-liquid ratio (E) Interaction of immersion time and immersion temperature (F) Interaction of solid-liquid ratio and immersion temperature

4. Conclusion

Studies have shown that blanching and sugar liquid dipping pre-treatment before hawthorn blackening can improve the efficiency of blackening and improve product quality. The best impregnation process is the concentration of sugar solution was 60%, the immersion time was 32 h, the ratio of material to liquid was 1:2.3, and the immersion temperature was 38 °C. The blackened hawthorn produced under these conditions has a sensory score of 98.14±0.03. The process provides a theoretical basis to produce blackened hawthorn and provides reference conditions to produce blackened fruits and vegetables.

References

[1] Nazhand A, Lucarini M, Durazzo A, et al. Hawthorn (Crataegus spp.): An updated overview on its beneficial properties. Forests, 2020, 11(5): 564.

[2] Martínez-Casas L, Lage-Yusty M, López-Hernández J. Changes in the aromatic profile, sugars, and bioactive compounds when purple garlic is transformed into black garlic. Journal of agricultural and food chemistry, 2017, 65(49): 10804-10811.

[3] Jing H, Kitts D D. Comparison of the antioxidative and cytotoxic properties of glucose-lysine and fructose-lysine Maillard reaction products. Food Research International, 2000, 33(6): 509-516.

[4] Moreno-Ortega A, Pereira-Caro G, Ordóñez J L, et al. Changes in the antioxidant activity and metabolite profile of three onion varieties during the elaboration of 'black onion'. Food chemistry, 2020, 311: 125958.

[5] Yang X H, Zhang Q, Wang J, et al. Innovative superheated steam impingement blanching (SSIB) enhances drying rate and quality attributes of line pepper. Information Processing in Agriculture, 2017, 4(4): 283-290.

[6] Ge S J, Lee T C. Kinetic significance of the schiff base reversion in the early-stage Maillard reaction of a phenylalanine– glucose aqueous model system. Journal of Agricultural and Food Chemistry, 1997, 45(5): 1619-1623.

[7] Karnjanapratum S, Supapvanich S, Kaewthong P, et al. Impact of steaming pretreatment process on characteristics and antioxidant activities of black garlic (Allium sativum L.). Journal of Food Science and Technology, 2021, 58: 1869-1876.