Effect of cooking conditions on quality of sweetened adzuki *an*

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Abstract: To produce high sensory quality sweetened adzuki *an*, the effects of cooking conditions including cooking time, heating power, sugar soaking time and soaking liquid pH on textural properties and sensory scores were evaluated using central composite experimental method. Blanching treatment and sodium tripolyphosphate were adopted to improve the mouthfeel of the whole bean *an* product. Results showed that the optimal parameters were as follows: cooking time of 50 min, heating power of 1.1 kW, sugar soaking time of 2 h and soaking liquid pH of 8.0, which resulted in the highest sensory score of 89.6. In this study, the effectiveness of the method to process sweetened whole bean adzuki *an* was validated and a sensory evaluation method for whole grain adzuki *an* product was developed.

Keywords: sweetened adzuki *an*, quality, cooking conditions, processing, sensory evaluation
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1 Introduction

Legumes play an important role in human nutrition. They are a good source of protein, starch[1], dietary fiber[2], polyunsaturated free fatty acids[3], minerals and vitamins, and also a preferred energy source for their low glycemic index and moderate postprandial glucose response[4]. As a variety of legumes, adzuki bean is widely accepted due to its desirable color, delicate flavor and soft texture[5]. These beans are widely prepared as ingredients of various dishes or directly processed into a bean paste called "*an*"[6].

An, a foodstuff coming from adzuki bean, has high market potential in East Asia due to its health-promoting components in bean products. Clinical studies have suggested that these components strengthen the immune system to decrease blood lipids and also protect the human body against cancers[7]. Colorful bean coats are rich in polyphenol compounds anthocyanins[8]. Cyaniding-3-glucoside in anthocyanins has higher antioxidant activity than vitamin E analogue[9]. Therefore, seed coats of adzuki beans have functional properties such as strong antioxidant capacity and the potential of reducing blood glucose[10], blood pressure[11,12] and liver damage[13]. Most traditional *an* foodstuff were processed using bean seeds without

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coat[14]. Major steps of processing *an* foodstuff include soaking, cooking, grinding and seed coat separation[15]. Separation of bean seed coat in traditional *an* foodstuff may eliminate tough taste caused by the existence of fiber in coats. This separation results in the loss of nutrients in seed coat and the reduction of *an* foodstuff yield. In the views of nutrition and yield, *an* processed using whole bean is the desirable foodstuff to meet the requirement of customers. Sodium tripolyphosphate agent was selected as a softening additive. Due to the changes of ionic strength and pH level[16-18], boiling beans in sodium tripolyphosphate solution can reduce bean coat hardness and the foodstuff's tough taste. The process is allowed to be used in the food processing industry in China[19]. The pH value of sugar soaking solution is an important factor to be investigated in this study.

Physical characteristics and quality indexes of bean paste products depend on bean varieties[15], processes including abrasion, grinding, cooking[20], material dimension including paste particle, bean size[21] and storage conditions[22]. Sensory quality is always the prime concern of many manufacturers and chefs that use ready-to-eat meals[23]. Sensory evaluation has been used to analyze the texture characteristics of adzuki bean paste (without bean coat) [13,24]. However, little study has been done to evaluate the effects of processing conditions on sensory quality of adzuki bean paste with bean coat. The objectives of the present study were to evaluate effects of cooking conditions in terms of cooking time, heating power, sugar soaking time and pH value on sensory score and texture properties of sweetened adzuki *an*. Results would provide valuable information on the processing technique of adzuki *an* (with seed coat) for manufacturers.

2 Materials and methods

2.1 Materials

Adzuki (strain of Longyin 09-05) was provided by Heilongjiang Academy of Agricultural Sciences, Harbin, China. Sodium tripolyphosphate was food grade. Premium white granulated sugar was purchased from local Metro Market. Barreled purified water for drinking was purchased from Robust Co. LTD (Harbin, China).

2.2 Bean coat softening test with addition of sodium tripolyphosphate

A pre-experiment was performed as following procedure. Adzuki beans (500±0.5) g were washed and placed in a cage (in Figure 1a). Then the cage was placed into a pot on an induction pot (in Figure 1b). Deionized water 5.0 L was added into the pot. A cover was placed on the top of beans (in Figure 1c) when water boiled and continued to cook the beans for 60 min. After cooking, beans were divided equally into two portions and soaked in 250 mL 62% sugar solution at 70°C for 1.5 h, respectively. One of the sugar solutions was adjusted to pH 8 by 10% sodium tripolyphosphate solution (0.75 mL) in advance. The other sugar solution without sodium tripolyphosphate was control sample.

Figure 1 Equipments for bean cooking

After sugar soaking, single bean was placed on the platform of a TA-texture analyzer (Stable Micro Systems, Godalming, UK) equipped with a 2 mm stainless needle (P/2N) to test TPA parameters of different samples. The equipment was set as follows: pre-test speed: 2.00 mm/s, test speed: 1.00 mm/s, post-test speed: 1.00 mm/s, strain: 50%, time: 5 sec and trigger force: 5.0 g. Each experiment was performed at six repeats.

2.3 Experimental design

Value range selected for each factor was based on the results from the preliminary experiments. A series of central composite design experiments was conducted to evaluate the quality as a function of independent variables, namely cooking time, heating power, sugar soaking time and soaking liquid pH value. The factors and their levels are shown in Table 1.

Table 1 Variables and levels in central composite design

Levels	X_1 Cooking time /min	X_2 Heating power/kW	X_3 Sugar soaking time/h	X_4 Soaking liquid pH
-2	20	0.7	0.5	7.6
-1	30	0.9	1.0	8.0
0	40	1.1	1.5	8.4
1	50	1.3	2.0	8.8
2	60	1.5	2.5	9.2

2.4 Preparation of unsweetened adzuki *an*

A new way of cooking was adopted to keep the wholeness of bean kernels. The cooking steps were below:

Blanching: deionized water 1.8 L was added into a pot to be heated by an induction cooker to reach 60°C in advance. Beans (500±0.5) g were washed and placed in a cylindrical steel cage with 0.2 mm mesh. Then the cage was placed into the pot and heated. When the water boiled, all of the water was removed immediately to get rid of the astringency of adzuki bean.

Precooking: deionized water 5.0 L at room temperature (22°C) was added into the pot anew. The hot bean kernels absorbed water quickly and extended thoroughly when soaking in cold water. Then the water was boiled for 15 min.

Main cooking: To avoid the beans crashing into each other during cooking, beans were soaked in water covered with a lid. The main cooking parameters (cooking time, heating power) were set according to Table 1.

2.5 Preparation of sweetened adzuki an

The cooked beans were soaked in 500 mL 62% sugar solution at 70°C for 0.5, 1.0, 1.5, 2.0 and 2.5 h, respectively. The pH value of sugar solution was adjusted by 10% sodium tripolyphosphate solution according to Table 1. After soaking, all the beans were transferred into an electric pan, stirred continuously at 100 °C until the extra water was eliminated.

2.6 Textural properties determination of the kernels

After sugar soaking, 50 g beans were sampled from multiple points of the container. About 25 adzuki bean kernels were selected by quartering method and placed one by one on the platform of TA-texture analyzer using a P/2N stainless probe to test TPA parameters as described in 2.2.

2.7 Sensory evaluation

Sensory characteristics of sweetened adzuki *an* with bean coat were evaluated by a trained panel which consisted of 10 male and 10 female personnel working in the food research institute. Panelists were trained to evaluate bean kernel wholeness, *an* flavor, bean coat hardness and overall acceptability. A commercial adzuki *an* was used as reference for all sensory characteristics. This *an* product was made from adzuki beans with seed coat (provided by Beijing Jingri Food Co.,Ltd).

All samples and references were served in a china container with a lid coded with a random number. Panelists were instructed to score sensory properties of samples according to the standard of sensory evaluation listed in Table 2. The final score was the sum of each item. Each panelist was provided with a partitioned booth illuminated with white light at room temperature (22°C) in the sensory lab.

Table 2 Standard of sensory evaluation

Item	A 25-21 points	B 20-16 points	C 15-11 points	D 10-6 points	E 5-1 points
Bean kernel wholeness	Integrity to totally broken				
An flavor	Strong and good to weak and bad				
Bean coat hardness	Low to high				
Overall acceptability	Excellent	Good	Acceptable	Poor	Fairly bad

2.8 Statistical analysis

Data were statistically analyzed by Design Expert (ver6.0.10) (Stat-Ease, Inc., Minneapolis, MN, US). All experiments were performed in triplicate and the results were represented as mean values.

3 Results and discussion

3.1 Effect of sodium tripolyphosphate for bean coat softening

Mean value test was proceeded by SPSS and the results were shown in Table 3.

Table 3 ANOVA results

	Sum of squares	DF	Mean square	F value	P value	Significant
Between groups	112.088	1	112.088	7.210	0.023	*
Intraclass	155.465	10	15.546			
Total	267.553	11				

Note: * Significant ($p<0.05$), N=6.

Statistical analysis results showed that there was significant difference between the two groups (p<0.05). This proved that sodium tripolyphosphate played an important role in softening the bean coat. Therefore, besides the cooking and soaking condition, sodium tripolyphosphate was also selected as one of the observing factors for *an* preparation.

3.2 Interaction of factors on sensory score of sweetened adzuki *an*

A multiple regression method was used to establish regression equation for the influencing factors. For Equation (1), extremely significant (p<0.001) linear relationship between cooking time (X_1) and sensory score of sweetened adzuki *an* was observed. Significant linear effect between sugar soaking time (X_3) and sensory score of sweetened adzuki *an* was also found (p<0.05). None of the interaction terms was significant. In quadratic terms, cooking time and heating power had the greatest effect on sensory score. Although the effect of soaking pH (X_4) was not significant at all, the result of single factor experiment was testified by method of mean value test that the sodium tripolyphosphate had an obvious effect on the bean coat hardness. It indicated that the quantity of sodium tripolyphosphate had little impact on the bean coat hardness after the pH of sugar solution reaching 7.6.

The importance of experimental factor was determined as follows: cooking time (F=33.12) > sugar soaking time (F=6.44) > heating power (F=2.22) > soaking pH (F=0.54). A linear regression equation (Equation (1)) was obtained from the regression results of factorial experiment:

$$y=46.63+8.39x_1+66.02x_2-50.57x_3-33.77x_4-0.054x_1^2-108.92x_2^2-9.33x_3^2+0.97x_4^2+0.51x_1x_2+0.24x_1x_3-0.46x_1x_4+0.18x_2x_3+16.41x_2x_4+9.40x_3x_4 \quad (1)$$

An optimum equation (Equation (2)) was obtained by dropping the non-significant items :

$$y=46.63+8.39x_1-50.57x_3-0.054x_1^2-108.92x_2^2 \quad (2)$$

Figure 2a-f showed the obvious changes of sensory score of sweetened adzuki *an* with cooking time and sugar soaking time and slight changes with heating power and soaking pH.

Table 4 Process variables and levels in central composite design arrangement and corresponding response value

Run	X_1	X_2	X_3	X_4	Y Sensory score, point
1	-1	-1	1	-1	57.2
2	1	-1	-1	1	61.3
3	-2	0	0	0	37.8
4	0	0	-2	0	64.7
5	0	0	0	-2	84.2
6	-1	1	1	1	60.3
7	0	0	0	0	89.7
8	1	1	-1	-1	68.4
9	0	0	0	2	86.7
10	0	-2	0	0	70.4
11	-1	1	-1	-1	45.5
12	0	0	0	0	70.1
13	1	1	1	1	68.8
14	1	-1	1	-1	89.6
15	-1	-1	-1	-1	60.7
16	1	-1	-1	-1	74.4
17	-1	1	-1	1	35.6
18	0	0	0	0	70.3
19	0	0	2	0	86.3
20	0	0	0	0	90.4
21	0	0	0	0	82.1
22	1	1	1	-1	80.8
23	0	2	0	0	64.4
24	1	-1	1	1	81.4
25	-1	-1	-1	1	50.1
26	2	0	0	0	88.9
27	1	1	-1	1	69.3
28	0	0	0	0	69.4
29	-1	1	1	-1	46.4
30	-1	-1	1	1	57.4

Table 5 Analysis of variance of each of the mathematical regression models

Source	Sum of Squares	DF	Mean Square	F value	P value	Significant
Model	5591.30	14	399.38	4.05	0.0054	**
X_1	3262.00	1	3262.00	33.12	<0.0001	***
X_2	218.41	1	218.41	2.22	0.1572	
X_3	634.48	1	634.48	6.44	0.0227	*
X_4	52.81	1	52.81	0.54	0.4753	
X_1^2	783.85	1	783.85	7.96	0.0129	*
X_2^2	521.01	1	521.01	5.29	0.0362	*
X_3^2	149.33	1	149.33	1.52	0.2372	
X_4^2	0.65	1	0.65	6.619E-003	0.9362	
X_1X_2	16.81	1	16.81	0.17	0.6854	
X_1X_3	23.52	1	23.52	0.24	0.6321	
X_1X_4	54.02	1	54.02	0.55	0.4704	
X_2X_3	2.500E-003	1	2.500E-003	2.538E-005	0.9960	
X_2X_4	27.56	1	27.56	0.28	0.6046	
X_3X_4	56.25	1	56.25	0.57	0.4615	
Residual	1477.46	15	98.50			
Lack of Fit	904.36	10	90.44	0.79	0.6505	
Pure Error	573.10	5	114.62			
Cor Total	7068.76	29				

Note: *** Extremely significant (p<0.001), ** Highly significant (p<0.01), * Significant (p<0.05).

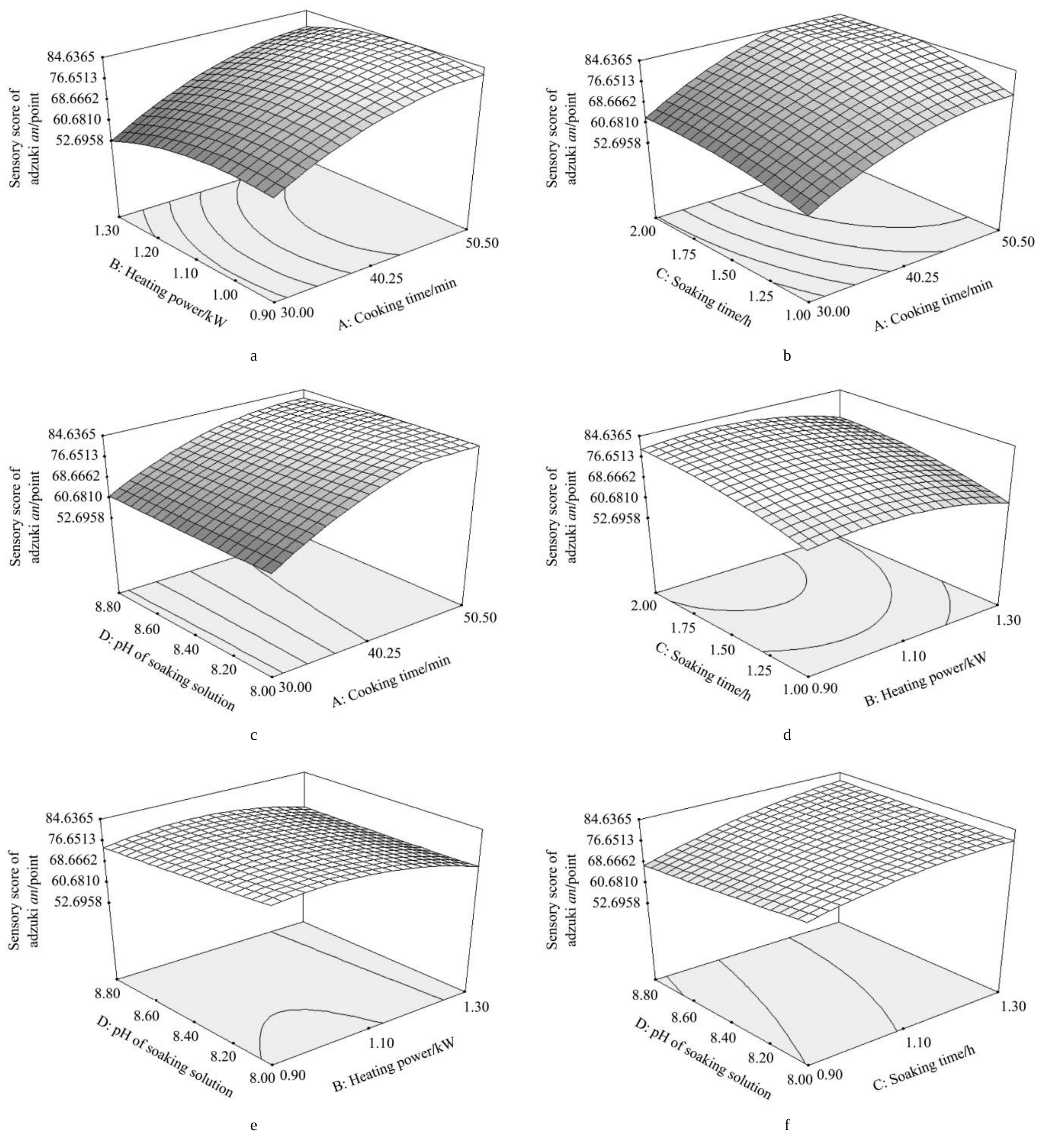


Figure 2 Interaction of cooking conditions on sensory score of sweetened adzuki an

The peak sensory score of sweetened adzuki *an* was obtained at cooking time 50 min and soaking time 2 h in Figure 2b. In general, cooked time of adzuki beans was 90-120 min before crushed into paste[21,25]. In this experiment, the cooking time was reduced by 50%, which was attributed to the blanching treatment that improved the dissolution rate of tannins from the bean coat. Normally, legume seeds contain a large amount of polyphenols as tannins form[26]. Complexes formed by tannins and other macromolecules strengthen the cell wall and reduce water penetration and swelling cause cell separation and hardness increase during cooking[27]. The reduction of tannins may improve the cooking characteristics of the beans. With prolonged soaking time, sodium tripolyphosphate degraded and softened bean coat fiber to reduce its hardness. The sensory score of adzuki *an* increase with the cooking time as shown in Figure 2a, 2b and 2c. Increase of cooking time results in decrease in hardness of cooked beans[28]. However, as shown in Figure 2c, e and f, sensory score of adzuki *an* declined with increasing pH value of soaking solution. This result was attributed to the destroying action of sodium tripolyphosphate on the wholeness of the bean kernel. The sensory score of adzuki an tended to slowly rise with the heating power and followed by a decline trend when heating power was up to 1.1 kW as shown in Figure 2a, 2d and 2e. This was due to the decrease in wholeness during heating caused by the changes in cell-wall pectin. As previously reported, firmness was highly correlated with soluble pectin in several beans[29] for the formation of soluble pectin by b-eliminative degradation of methylated pectin[30-32].

The correlation coefficient between sensory evaluation and sensory score of sweetened adzuki *an* were shown in Table 6.

Table 6 Correlation coefficient between sensory evaluation and sensory score of sweetened adzuki *an*

Correlation coefficient	Bean kernel wholeness	An flavor	Bean coat hardness	Overall acceptability
Sensory score	0.1619	0.9332**	0.9349**	0.9051**

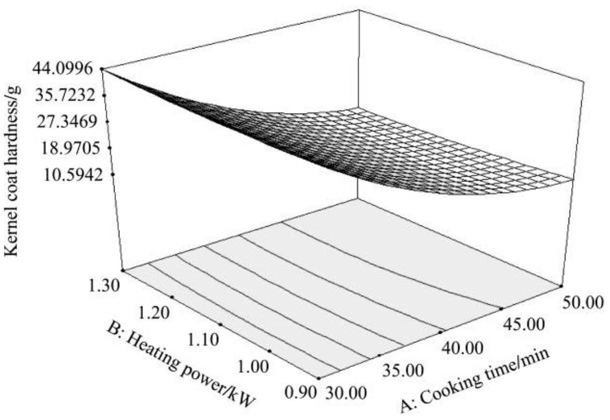
Note: $r_{0.05}$= 0.355; $r_{0.01}$=0.456.

Among sensory evaluation items, *an* flavor, bean coat hardness and overall acceptability were highly correlated with the sensory score of sweetened adzuki *an*.

3.3 Interaction effect of factors on bean coat hardness analysis by texture analyzer

Besides sensory evaluation, bean coat hardness can also be investigated by texture analyzer. The interaction effects on bean coat hardness were shown in Figure 2.

The kernel coat hardness decreased with the increase of cooking time and heating power. This results from the boiling water impinging bean kernel to break the fiber filled in the kernel coat. A nearly straight line can be seen along the soaking time axis in the two-dimensional contour plot of Figure 3a, 3b and 3c. The results showed that soaking time, heating power and soaking liquid pH in comparison with cooking time had slight effect on the bean coat hardness. The hardness of beans heated with higher cooking power, showed little softening effect but would with longer cooking time. When cooked for 40 min, the interaction of soaking time and pH value on the kernel coat hardness as presented in Figure 3f reached a minimum hardness of 15.20 g. This result could be ascribed to the presence of sodium tripolyphosphate. It was reported that salt solutions improve heat-transfer properties of solution, increase water-absorption capacity and water-holding capacity[33,34]. Sodium tripolyphosphate may decrease the hardness of the bean coat for its function of chelating, emulsion and buffering[16,35-38]. Also, Figure 2f showed a different trend that the bean coat hardness increased with increasing pH of the soaking sugar solution. This phenomenon was attributed to the high temperature and high concentration sugar solution (62% at 70°C) with high osmotic pressure, which accelerated replacement speed of the water inside the bean kernels with sugar, and enhanced the cell wall hardness. The changes of cooked beans quality in terms of color, texture and flavor induced by sugar soaking is still unclear, hence further investigation is necessary.



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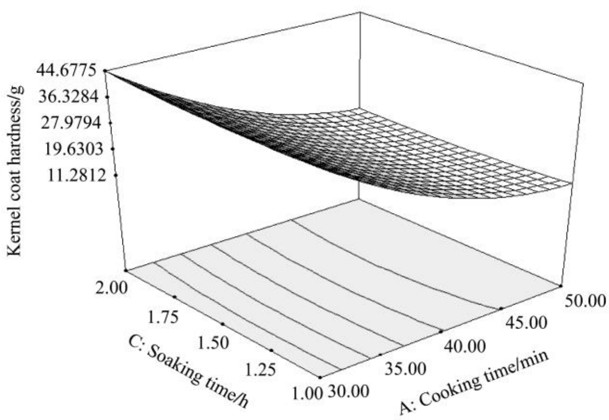

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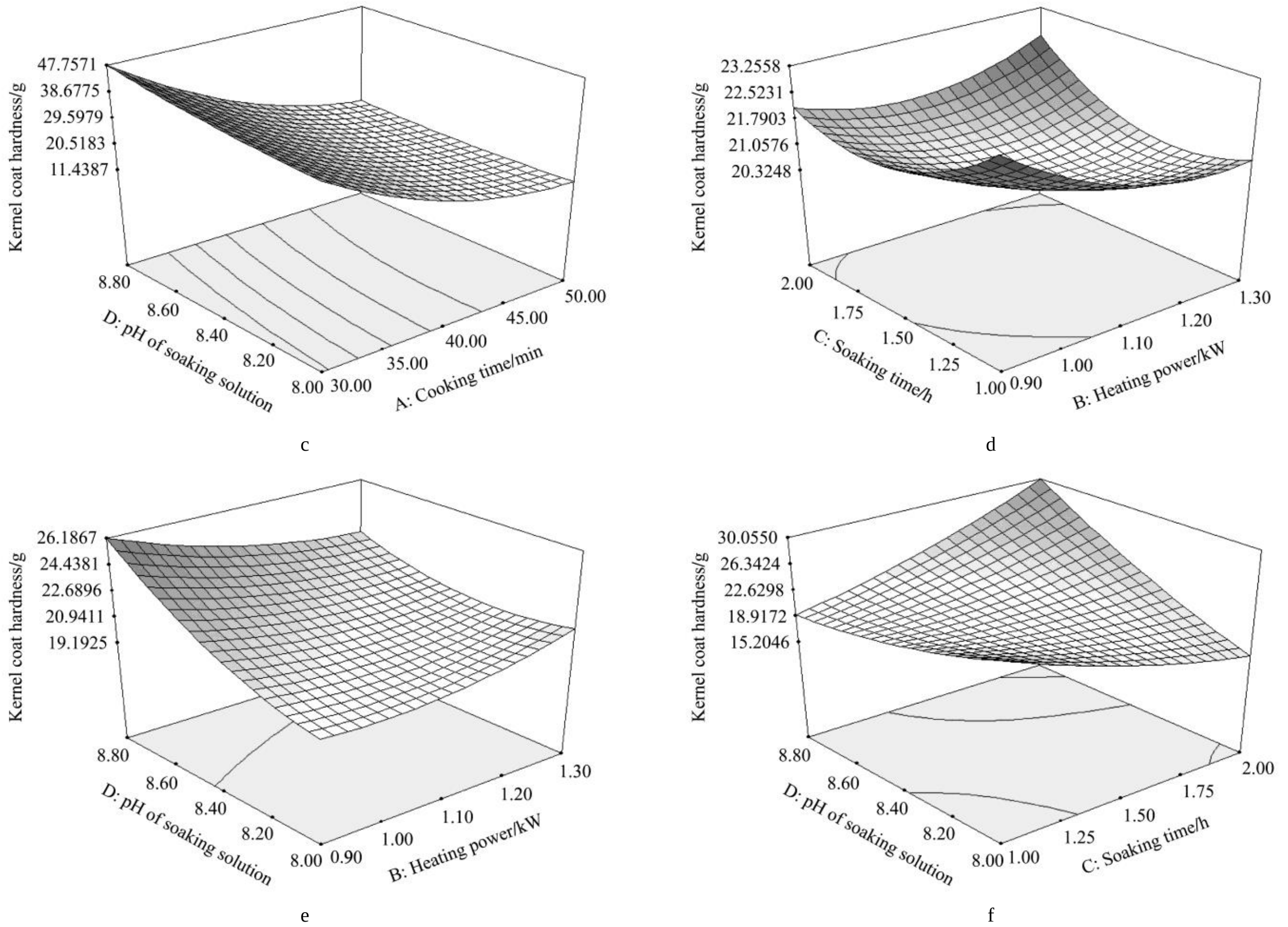

Figure 3 Interaction of cooking conditions on kernel coat hardness by texture analyzer

3.4 Optimization of parameters for processing of sweetened adzuki *an* with bean coat

As shown in Table 7, the optimization values of the model were in good consistent with the validation values.

Table 7 Optimization results and validation values of test

Factors	Cooking time/min	Heating power /kW	Sugar soaking time/h	Soaking pH	Predict value	Validation value
Optimization value	50	1.02	1.98	8.0	90.7	—
Validation value	50	1.10	2.00	8.0	—	89.6

4 Conclusions

The edible bean *an* with bean coat has high acceptability of monotonous diets of the world especially in the East. Consumer's sensory preferences are an important concern in industrial production. Cooking time has the greatest effect on sensory score, followed by sugar soaking time and heating power, while the pH value of soaking solution has the least effect. The optimum parameters were developed as follows: 50 min of cooking time, heating power of 1.1 kW, 2 h of sugar soaking time and soaking pH of 8.0, and the sensory score could reach 89.6 points.

An important finding of this study was to validate the effectiveness of the method to process sweetened adzuki *an* with bean coat and build a sensory evaluation method for whole grain adzuki *an* foodstuff. This is important from both an economic and an industrial point of view. This study further confirmed the result of previous research that cooking time and 10% sodium tripolyphosphate buffer solution decreased coat hardness of the cooked beans. The quality changes of cooked beans in terms of color, texture and flavor during sugar soaking need to be further investigated in the future. Chemical properties of sweetened adzuki *an* with bean coat, such as total antioxidant activity and DPPH (1,1-Diphenyl-2-picrylhydrazyl radical 2,2-Diphenyl-1-(2,4,6-trinitrophenyl) hydrazyl) radical scavenging activity, should also be investigated in comparison with the regular *an* products in the market.

Acknowledgments

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