Advance Journal of Food Science and Technology 5(4): 464-468, 2013
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: December 13, 2012 Accepted: January 19, 2013 Published: April 15, 2013

Process Optimization and its Impacts on Physical Properties of Instant Rice

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Abstract: In order to develop production technology of instant rice, this study was undertaken with the soaking and processing conditions to improve the quality of instant rice. Soaking temperature, soaking time and adding amount of water were all investigated to select the optimal soaking condition by measuring water absorption and moisture content. Pseudo-level method of L_9 (3^4) orthogonal design tests were adopted to optimize the cooking process by physical properties mainly including hardness, adhesiveness and moisture content. Results showed that physical properties had significant linear relationship with three processing factors by multiple linear regressions and the optimal cooking process was maintaining pressure at 80 KPa for 4 min and stewing rice for 15 min.

Keywords: Instant rice, physical properties, process optimization, soaking condition

INTRODUCTION

Instant rice is rice that can be rehydrated in a relatively short period of time, either by the addition of hot water or by the addition of water and microwave heating, after which the rice is ready for consumption (Lee and Wissgott, 2001). Instant rice is becoming more and more popular. However, instant rice still exist some problems, especially lower hardness and less sticky (Prasertand Suwannaporn, 2009). Many studies have shown that the hydration kinetics is affected by soaking time and temperature and the solute concentration (Shittu*et al*., 2004; Badau*et al*., 2005). To obtain instant rice, raw rice is cooked in order to gelatinize its starch (Rewthong *et al*., 2011). Degree of gelatinization was related to cooking method, cooking time and/or temperature. The effects of cooking conditions on the quality of cooked rice were investigated (Leelayuthsoontorn and Thipayarat, 2006). High pressure cooking process resulted in more homogeneous gelatinization (Baz *et al*., 1992)

In this study, the pseudo-level method of L_9 (3^4) orthogonal design tests were applied to research the impact of cooking conditions on the physical properties of instant rice, namely hardness, adhesiveness and moisture content. The relationships between physical properties and processing factors, including cooking pressure, pressure keeping time and stewing time, were also investigated

MATERIALS AND METHODS

Materials: A sample of rice variety named Longjingxiang was obtained from Heilongjiang Agricultural Company Limited. Its moisture content was 13.84%. The sample rice was kept at 4°C.

Instruments: Pressure cooker of adjustable voltage (Supor Company Limited, PRC), Texture Analyzer TA-XT2 (Stable Micro Systems, UK), freezing refrigerator (New Brunswick Scientific, UK).

Methods:

Soaking conditions: This experiment was carried out on the sample rice at 25, 35 and 45°C, respectively in a thermostatic water bath. Five grams of sample rice wasremovedwith residual surface water at predetermined time interval of 10 min up to 2 h and reweighed until the increase in weight was less than 0.001 g. The ratio of the increase during soaking in the weight before soaking was calculated as water absorption.

Preparation of cooked rice samples: One hundred grams of rice was washed three times quickly and then soaked in 160 g water at 25°C for 60 min. Both water and rice were poured into the pressure cooker of adjustable voltage. The soaked rice was cooked at 80 KPa for 5 min and stewed for 20 min. About 220 g of cooked rice were frozen quickly in the -80°C freezing refrigerator for 3 h, finally kept at-18°C for 48 h prior to microwave reheating.

Texture profile analysis: The TPA of cooked rice was measured with a Texture Analyzer TA-XT2. Sample undergoes a “two-bite” compression by using a 5 kg load cell. It was compressed 3 mm with a time interval of 5 s at a speed of 0.5 mm/s. This experiment was repeated twelve times. After eliminating the deviation curves, results are reported as an average value.

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Table 1: Control factors and relative selected levels

Control factor	Level I	II	III
A: cooking pressure	80 KPa	50 KPa	80 KPa
B: pressure keeping time	4 min	5 min	6 min
C: column	1	2	3
D: stewing time	10 min	15 min	20 min

Table 2: The impact of cooking pressure on the physical properties of instant rice

Cooking pressure /KPa	Hardness /g	Adhesiveness /(g.sec)	Moisture content /%
80	1762.20	116.55	60.69
50	1905.17	101.53	57.63

Moisture content: The initial moisture content of sample was determined on wet basis using the standard method of AOAC (2003). The moisture content was measured for the replicated samples by the air oven method at 105°C for 3 h. The samples were weighed to 0.001 g accuracy with a balance.

Experimental design: Various factors including cooking pressure, pressure keeping time and stewing time were studied individually in order to determine the effect on hardness and moisture content. As cooking pressure has only two levels, while other factors has three levels, each factor was optimized by pseudo-level method of L_9 (3^4) orthogonal design tests (Table 1), which included a column and a dummy level of cooking pressure. Finally, the optimum conditions were selected to perform the confirmatory experiment.

Since the pseudo-level method of orthogonal design tests were adopted, related data analysis should be adjusted lightly, especially the standard deviation of cooking pressure in the following:

$$T = \sum x_i \quad SS_T = \sum x_i^{\,2} - \frac{T^2}{n}$$

$$SS_A = \frac{(K_{11}+K_{31})^2}{6} + \frac{K_{21}^{\,2}}{3} - \frac{T^2}{9} \quad SS_e = SS_{空} + \frac{(K_{11}-K_{31})^2}{6}$$

$$SS_j = \frac{K_{1j}^{\,2}}{3} + \frac{K_{2j}^{\,2}}{3} + \frac{K_{3j}^{\,2}}{3} - \frac{T^2}{9}$$

(when j = 2, 3, 4, SS_j is successively parallel to SS_B, $SS_{空}$ and SS_c)

Statistical analysis: Data obtained from quality parameters of reheated rice and were subjected to analysis of variance. The data processing, programming and the regression analysis were performed using Excel and SPSS.

RESULTS AND DISCUSSION

Effect of soaking condition on water absorption: The water absorption curves at 45°C (Fig. 1) showed a quicker increase during the first minutes and finally got

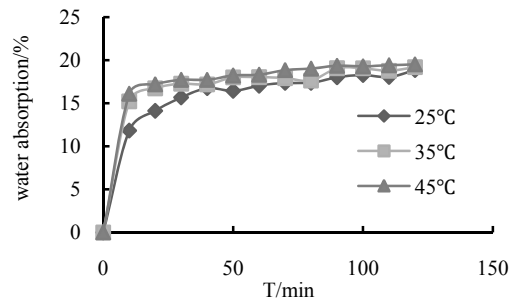

Fig. 1: The impact of soaking conditions on water absorption

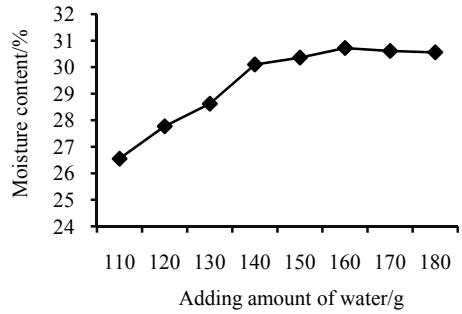

Fig. 2: The impact of adding amount of water on moisture content

the slightly higher than at 25 and 35°C. While, three absorption curves nearly came to the same saturation moisture content of 30.84%. The hydration curve (Fig. 2) showed that moisture content increased significantly when adding amount was 110 to 140 g. When the amount increased continuously, the increasing tendency became gradual and it came to the final saturation moisture content and kept balanced with 160 g. Hence, soaking rice for 60 min at 25°C was to be adopted.

Some studies showed that the texture profile analysis, mainly including hardness and adhesiveness can be adopted to evaluate the sensory quality of the product (Ghasemi *et al*., 2009; Huahan *et al*., 2012; Park *et al*., 2001). Therefore, hardness and adhesiveness are important parameters for the evaluation of cooked rice texture.

Effect of cooking pressure on the physical properties: Table 2 showed that a decrease in cooking pressure caused a harder and less sticky texture, while rice at 80 KPa owned higher moisture content. High pressure induced high gelatinization, which resulted in a softer texture, so we choosing 80 KPa as the third dummy level in the pseudo-level method of L_9 (3^4) orthogonal design tests.

Effect of pressure keeping time on physical properties: In Fig. 3 and 4, when keeping pressure for 2 min, it was so quick that rice was not fully gelatinized, therefore, reheated rice was quite hard and

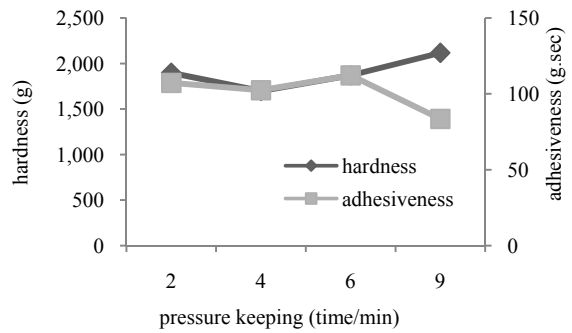

Fig. 3: The impact of pressure keeping time on TPA

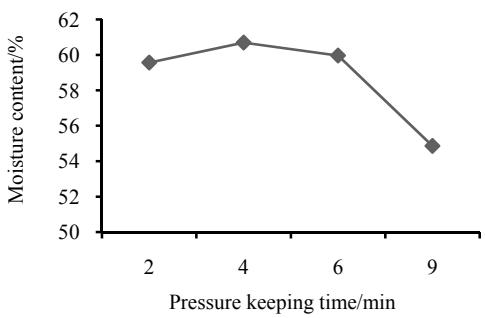

Fig. 4: The impact of pressure keeping time on moisture content

its moisture content was not high enough. After keeping for 4 min, the rice has the lowest hardness and highest moisture content, achieving the best sensory quality. An increase for larger 6 min caused a bigger hardness, a lower adhesiveness and lower moisture content. However, rice was inclined to a little paste for 9 min, which caused a poor quality.

Effect of stewing time on physical properties: The moisture content of rice decreased with stewing time increasing (Fig. 5 and 6). If rice did not undergo stewing rice period, the gelatinization would not be homogeneous, while, stewing time larger 40 min, excessive loss from evaporation led to increase in hardness, decrease in adhesiveness and moisture content.

Process optimization: Table 3 showed that the optimum processing was A1B1C2 when measured by the hardness, A1B2C1 when measured by the adhesiveness and A3B1C2 when measured by the moisture content. As the pseudo-level method was adopted, A3 was equal with A1. Consequently, we should arrange the confirmatory experiment, namely A1B1C2 and A1B2C1.

According to Table 4, cooking pressure and pressure keeping time had significant or extremely

Table 3: Cooking methods and test results

	Factors				Evaluation index		
No.	Cooking pressure/KPa	Pressure keeping time/min	Column	Stewing time/min	Hardness/g	Adhesiveness / (g·sec)	Moisture content/%
1	80	4	1	10	1700.62	106.98	61.62
2	80	5	2	15	1667.52	103.41	61.04
3	80	6	3	20	2671.84	90.66	56.80
4	50	4	2	20	2161.57	79.51	58.07
5	50	5	3	10	1917.53	103.75	56.42
6	50	6	1	15	2661.02	81.50	55.22
7	80	4	3	15	1617.71	96.37	61.50
8	80	5	1	20	2090.59	97.67	59.45
9	80	6	2	10	2517.02	100.32	58.88
Hardness							
$\overline{K}_{1j}$	2013.33		1826.63		2150.74		2045.06
$\overline{K}_{2j}$	2246.71		1891.88		2115.37		1982.08
$\overline{K}_{3j}$	2075.11		2616.63		2069.03		2308.00
Range	233.38		789.99		81.72		325.92
Optimum level	A1		B1				C2
Adhesiveness							
$\overline{K}_{1j}$	100.35		94.29		95.38		103.68
$\overline{K}_{2j}$	88.25		101.61		94.41		93.76
$\overline{K}_{3j}$	98.12		90.83		96.93		89.28
Range	12.12		10.78		2.51		14.40
Optimum level	A1		B2				C1
Moisture content							
$\overline{K}_{1j}$	59.82		60.40		58.76		58.97
$\overline{K}_{2j}$	56.57		58.97		59.33		59.25
$\overline{K}_{3j}$	59.94		56.97		58.24		58.11
Range	3.37		3.43		1.09		1.15
Optimum level	A3		B1				C2

Table 4: Analysis of variance

Source of errors		S.S.	df	M.S.	F
Hardness	A	82004.40	1	82004.40	22.96*
	B	1153605.14	2	576802.57	161.53**
	C	179326.51	2	89663.26	25.11*
	Error	10712.72	3	3570.91	
Adhesiveness	A	241.02	1	241.02	70.27**
	B	182.25	2	91.13	26.57*
	C	325.79	2	162.90	47.49**
	Error	10.29	3	3.43	
Moisture content	A	21.93	1	21.93	37.17**
	B	17.81	2	8.91	15.10*
	C	2.14	2	1.07	1.81
	Error	1.79	3	0.60	

Table 5: Regressive analysis of evaluation index and processing parameters

Regressive equations	Significance (α value)
Hardness = 214.792 - 6.750P + 394.997Pt + 26.294St	0.041
Adhesiveness = 100.206 + 0.366P - 1.730Pt - 1.440St	0.061
Moisture content = 60.926 + 0.110P - 1.715Pt -0.087St	0.002

P: Cooking pressure; Pt: Pressure keeping time; St: Stewing time

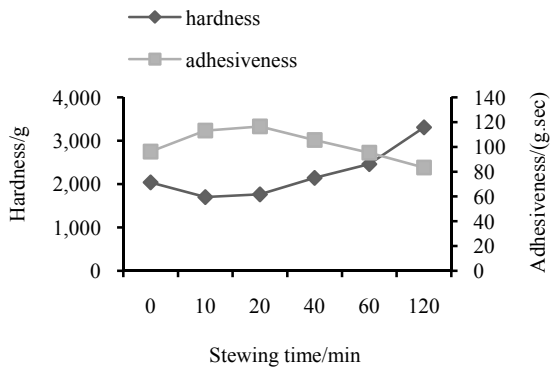

Fig. 5: The impact of stewing rice time on TPA

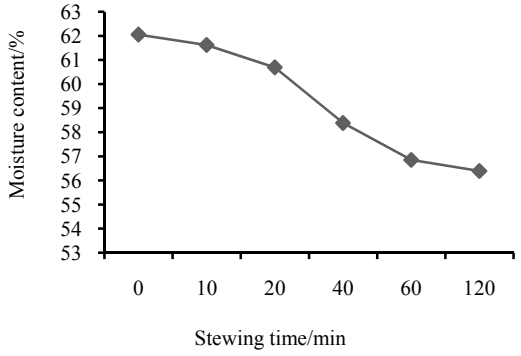

Fig. 6: The impact of stewing rice time on moisture content

significant effect on hardness, adhesiveness and moisture content. Stewing time had significant influence on hardness and adhesiveness, while had no great influence on moisture content. It was apparent in Table 5 by multiple linear regressions that evaluation indexes separately had extremely significant linear relationship with cooking pressure, pressure keeping time and stewing time.

Confirmatory experiments showed that the rice owned a softer texture and higher moisture content when maintaining pressure time set at 4 min than 5 min. In line with sensory observation, the optimal cooking process was that rice was cooked at 80 KPa with keeping pressure for 4 min and stewed for 15 min.

CONCLUSION

Processing conditions affected physical properties including hardness, adhesiveness and moisture content of instant rice. Soaking process can help rice achieve the saturation moisture content (about 30.84%). The hardness and moisture content decreased as cooking pressure increased, while adhesiveness had adverse effect. The physical properties separately had extremely significant linear relationships with each processing parameter. After comprehensive evaluation, the optimal cooking process was maintaining pressure at 80 KPa for 4 min and stewing for 15 min.

REFERENCES

AOAC, 2003.AOAC Official Method 942.23, Thiamin (Vitamin B_1) in Foods, Florimetric Method, AOACOfficial Method of Analysis, 45.1.05. AOAC International, Gaithersburg, MD.

Badau, M.H., E. Nkama and I.A.Jideani, 2005. Water-absorption characteristics of various pearl millet cultivars and sorghum grown in Nigeria. J. Food Process Eng., 28:282-298.

Baz, A.A., J.Y. Hsu and E. Scoville, 1992. Preparation of Quick Cooking Rice. U.S. Patent 5,089, 281.

Ghasemi, E., M.T.H. Mosavian and M.H.H. Khodaparast, 2009. Effect of stewing in cooking step on textural and morphological properties of cooked rice. RiceSci., 16(3):243-246.

Huahan, C., Y.K. Chen and H.C. Chang, 2012. Evaluation of physicochemical properties of plasma treated brown rice. Food Chem., 135(1): 74-49.

Lee, E. and U. Wissgott, 2001. Instant Soakable Rice. U.S. Patent 2001006696.

Leelayuthsoontorn, P. and A. Thipayarat, 2006. Textural and morphological changes of jasmine rice under various elevated cooking conditions. Food Chem., 96(4): 606-613.

Park, J.K., S.S. Kim and K.O. Kim, 2001. Effect of milling ratio on sensory properties of cooked rice and on physicochemical properties of milled and cooked rice. Cereal Chem., 78(2): 151-156.

Prasert, W. and P. Suwannaporn, 2009. Optimization of instant jasmine rice process and its physicochemical properties. J. Food Eng., 95(1): 54-61.

Rewthong, O., S. Soponronnarit, C. Taechapairojb, P. Tungtrakulc and S. Prachayawarakornd, 2011. Effects of cooking, drying and pretreatment methods on texture and starch digestibility of instant rice. J. Food Eng., 103(13): 258-264.

Shittu, T.A., S.O. Awonorin and A.O. Raji, 2004. Evaluating some empirical models for predicting water absorption properties in African breadfruit seeds. Int. J. Food Properties, 7(3): 585-602.