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Cast a New Light on the Retrogradation-Retardation Technology for Rice Cake

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Abstract. The present study was carried out to determine optimum manufacturing condition for maintenance of rheological properties and retrogradation retardation of rice cake during shelf life. It has been selected four key elements in each manufacturing procedure. We investigated the effect of added moisture volume(in step 1), cooling temperature for steamed dough(in step 2), quantity of added wheat flour(in step 3) and physical impacting force(in step 4) on several rheological and the related quality properties of rice cake. In this study, we set up experimental condition as variable in each process as following; adding moisture volume (15~24%), cooling temperature (65~95 ℃), different volume of starch (wheat flour, 0~0.7% w/w of swelling rice), and punching time (2~20 min, with rotor speed of 400 rpm). At results, we found that the best standard manufacturing procedure for retrogradation-retardation technology(RRT) is moisture (24%), cooling down under 65 ℃ for steamed dough, wheat starch (0.2%), and punching for 13 min with rotor speed of 400 rpm. It can be assumed that the principle of RRT is not one factor but interaction among moisture content, temperature, punching time, and grain starch property.

Keywords: retrogradation, non-glutinous rice, rice cake, shelf life

1. Introduction

It is known that retrogradation profoundly influences physiochemical quality and shelf life of starch containing foods. Starch retrogradation is a non-equilibrium thermo reversible recrystallization process generally, which take place in three consecutive steps: nucleation, propagation, and maturation [1]. With recent academic reports and research papers on starch retrogradation, there are many studies regarding factors that can reduce the degree of retrogradation of cooked starchy food. Starch retrogradation has been shown to be influenced by the length of amylopectin chain [2], the content of amylose [3], co-recrystallization of amylase with amylopectin [4], oligosaccharides [5], and nonstarch components [6]-[8]. Rice(*Oryza sativa* L.) is a primary food resource, and more than ninety percent of rice yield in the world is produced and consumed in Asia. In Fareast Asian countries, including Korea, Japan, and China, rice has been the staple food in local traditions including ancestral rites, religious ceremonies, folk customs, agricultural rituals, and seasonal observances. Celiac disease is a digestive disorder found in patients who are genetically susceptible, with the resulting damage to the small intestine by an interference with the absorption of nutrients [9]. There are many ongoing studies regarding starches that can either reduce wheat allergy or replace the wheat [10], [11]. Nevertheless, cooked starchy food such as rice cake has a short shelf life as a result of retrogradation [12]. It is therefore important to develop production technology that will help prolong shelf life and maintain their texture right after production by controlling the retrogradation process. For rice-based food to be recognized as more effective and safer source of carbohydrates in the process of distribution, inhibiting the deterioration of texture by starch retrogradation is an indispensable key to solving the problems of rice processing industry.

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2. Materials and Methods

2.1. Preperation of Rice Cake

Rice(*Oryza sativa cv. Chucheongbyeo)* was cultivated in Icheon city, Gyeonggido, Korea. Each factor as variable of RRT process adapted in each step 1, 2, 3, and 4 was described the below of each table in section of results. Non-glutinous rice cakes were prepared with retrogradation-retardation technology and stored at 20 ℃ for 24 hr. RRT based on the Korean traditional manufacturing process[13] is described in Table I in detail. And, each manufacturing condition was explained in each section of experimental result.

Table I: Retrogradation-retardation technology for rice rice cake made from non-glutinous rice

manufacturing procedure	Manual	Variables in each step
Washing and Soaking	Wash 3 times and soaking with tap water for 3 hr	
Draining	After soaking, removal of water residue of rice surface	
Grinding	Grinding and sieving finely(20 mesh) with 1.0% of salt(w/w, basis swollen rice)	
Adjusting moisture content	Adding water and kneading it evenly	**Key process 1**
Steaming	Steaming for 10 min	
Cooling	Cooling down	**Key process 2**
Adding starch	Adding wheat flour	**Key process 3**
Impacting(physical force)	Impacting at 450rpm	**Key process 4**
Shaping and sampling	Shaping long and cylinder-typed rice cake Criteria for product baseline(3.5 cm diameter and 4.0 cm high)	

2.2. Texture Profile Analysis of Rice Cake

The texture properties of rice cake adapted with different experimental manufacturing conditions were determined by a Texture Analyzer (Stable Microsystems, UK). The gel cylinder (3.5 cm diameter and 4.0 cm high) was compressed at a speed of pre-test 5.0 mm/s, test 2.0 mm/s, and post-test 2.0 mm/s to 80% deformation with a cylindrical probe SMS/P4 under the texture profile analysis (TPA) test mode. The time interval between the end of the first compression and the second compression was 3 sec.

2.3. Observation of Structure Using Scanning Electron Microscopy(SEM)

Microstructural properties of non-glutinous rice cakes prepared under the five different experimental conditions using a scanning electron microscopy (S-4300, Hitachi, Tokyo, Japan). The samples were mounted on an aluminum stub using double-sided stick tape, coated with a thin film of gold (10 nm), and then examined at an accelerating voltage at 16 kV.

2.4. Degree of Retrogradation of Rice Cake

The degrees of retrogradation was assessed by α-amylase iodine method [14] with slight modification.

2.5. Statistical Analysis

Experimental data were analyzed using one-way analysis of variance(ANOVA) and expressed as mean values standard deviations. Duncan's test was conducted to examine significant differences among experimental mean values($p<0.05$). The software used for all analyses was SPSS 9.0.

3. Results and Discussion

3.1. Preparation of Rice Cake

The present study was performed to determine optimum manufacturing condition for maintenance of physiochemical properties and retrogradation retardation of rice cake during shelf life. We selected four key elements in each manufacturing procedure. It was investigated the effect of added moisture volume(in step 1), cooling temperature for steamed dough(in step 2), quantity of added wheat power(in step 3) and physical punching time(in step 4) on several rheological and the related quality properties of rice cake. RRT based on the Korean traditional manufacturing process is described in Table I in detail.

3.2. Texture Profile Analysis of Rice Cake

The important parameters for evaluation of the texture of rice cake include hardness, adhesiveness, springiness, gumminess, cohesiveness and chewiness [15]. Rice cake is a food made with non-glutinous rice and cooked by steaming. Cooked rice starch goes through gelatinization and retrogradation processes. When this starch is kept at room temperature, the structure of starch molecules turns from a loose gel state to a tightly bound state. With the loss of inner moisture content of non-glutinous rice cake, it gets to have a net-shaped structure through this series of process.

3.2.1. Effect of adding water volume as variable of RRT on TPA-Key process 1

In step 1, it was investigated the effect of added moisture volume on six texture profiles of rice cake prepared with different experimental condition related with key process 1. Experimental formula were controlled to assess the optimum quantity of adding water from 15 to 24% as variable, and the other steps(key process 2, 3, and 4) are fixed. At results, it was maintained quality in hardness, the core factor related with retrogradation, of rice cake prepared with 24% of adding water volume for 24 hr at the storage of 20 ℃ (Table II).

Table II: Effect of adding water volume on TPA of rice cake-Key process 1

Texture parameters	Storage time(hr)	Adding water volume (%)			
		15%	18%	21%	24%
Hardness(g)*	0	1520.47[a]	1001.41[b]	830.87[c]	521.45[d]
	24	2105.82[a]	1920.91[b]	1763.77[c]	672.36[d]
Adhesiveness	0	-294.50	-292.70	-284.93	-282.73
	24	-278.21	-274.72	-268.86	-268.53
Springiness	0	0.87	0.87	0.87	0.86
	24	0.85	0.85	0.85	0.85
Cohesiveness	0	0.69	0.69	0.69	0.69
	24	0.60	0.59	0.57	0.62
Gumminess*	0	1322.81[a]	703.46[b]	577.21[c]	358.81[d]
	24	1789.95[a]	1102.53[b]	1074.06[b]	423.24[c]
Chewiness*	0	912.74[a]	619.58[b]	503.60[c]	304.29[d]
	24	1076.97[a]	897.57[b]	873.32[b]	359.04[c]

Experimental formula were controlled to assess the optimum quantity of adding water from 15 to 24% as variable, and the other steps(key process 2, 3, and 4) are fixed. Data represent means ± SD of 10 samples of non-glutinous rice cake prepared with each manufacturing condition. Values with different superscripts within the same column are significantly different ($p<0.05$). *Signification at $p<0.001$.

3.2.2. Effect of cooling temperature as variable of RRT on TPA-Key process 2

In step 2, it was considered the key element of non-hardening rice cake manufacturing process is cooling down the steamed dough to appropriate temperature. It was investigated the effect of cooling temperature on six texture profiles of rice cake prepared with different experimental condition in key process 2. Experimental formula were controlled to assess the optimum temperature of cooling dough from 95 to 65 ℃ as variable, and the other steps(key process 1, 3, and 4) are fixed. At results, it was maintained quality in hardness, of rice cake prepared with cooling down to 65 ℃ for 24 hr at the storage of 20 ℃ (Table III).

3.2.3. Effect of addition quantity of wheat flour as variable of RRT on TPA-Key process 3

In step 3, it was investigated the effect of added wheat flour volume on six texture profiles of rice cake prepared with different experimental condition in key process 3. Experimental formula to evaluate the optimum quantity of adding wheat flour is set up as following; different volume of wheat flour(from 0 to 0.7%) is considered as variable, the other steps(key process 1, 2, and 4) are fixed. At results, it was maintained quality in hardness of rice cake prepared with 0.2% of adding wheat flour as minimum for 24 hr at the storage of 20 ℃ (Table IV).

3.2.4. Effect of punching time as variable of RRT on TPA-Key process 4

In step 4, it was investigated the effect of added moisture volume on six physiochemical parameters related texture of rice cake prepared with different experimental condition in key process 3. Experimental formula were controlled to assess optimum punching time from 2 to 20 min for impacting physical force as variable, and the other steps(key process 1, 2, and 3) are fixed. At results, it was maintained quality in hardness and chewiness of rice cake impacting as physical force with 13 min at 400 rpm (Table V).

Table III: Effect of cooling temperature for steamed dough on TPA of rice cake-Key process 2

Texture parameters	Storage time(hr)	Cooling temperature (℃)			
		95℃	85℃	75℃	65℃
Hardness(g)	0	643.95	638.19	653.20	635.87
	24	2128.02^{a}	1736.23^{b}	1033.13^{c}	760.21^{d}
Adhesiveness	0	-283.03	-273.23	-296.08	-302.60
	24	-175.04	-780.68	-374.33	-363.03
Springiness	0	0.85	0.85	0.85	0.85
	24	0.88	0.82	0.84	0.86
Cohesiveness	0	0.65	0.66	0.67	0.66
	24	0.54	0.59	0.61	0.65
Gumminess	0	421.13	422.08	436.91	419.60
	24	1149.75^{a}	1023.60^{b}	645.96^{c}	594.12^{d}
Chewiness	0	359.55^{ab}	358.97^{ab}	370.21^{a}	357.11^{ab}
	24	1010.19^{a}	840.76^{b}	541.65^{c}	511.86^{c}

Experimental formula were controlled to assess the optimum temperature of cooling dough from 95 to 65℃ as variable, and the other steps(key process 1, 3, and 4) are fixed. Data represent means ± SD of 10 samples of non-glutinous rice cake prepared with each manufacturing condition. Values with different superscripts within the same column are significantly different (p<0.05).

Table IV: Effect of addition quantity of wheat flour on TPA of rice cake-Key process 3

Texture parameters	Storage time(hr)	Addition wheat flour (%)			
		0%	0.1%	0.2%	0.7%
Hardness(g)*	0	749.98^{a}	694.65^{b}	587.72^{c}	559.21^{c}
	24	2676.50^{a}	1,593.86^{b}	745.24^{c}	613.96^{d}
Adhesiveness	0	-260.53	-282.01	-325.75	-327.14
	24	-270.68	-288.11	-286.83	-285.76
Springiness	0	0.87	0.86	0.83	0.83
	24	0.96	0.83	0.84	0.85
Cohesiveness	0	0.68	0.68	0.66	0.67
	24	0.63	0.63	0.62	0.64
Gumminess*	0	511.57^{a}	480.88^{a}	387.09^{b}	372.37^{b}
	24	1482.85^{a}	955.69^{b}	464.65^{c}	395.87^{d}
Chewiness*	0	446.15^{a}	414.38^{a}	321.72^{b}	308.42^{b}
	24	1421.37^{a}	796.68^{b}	390.35^{c}	336.41^{c}

Experimental formula to evaluate the optimum quantity of adding wheat flour is set up as following; different volume of wheat flour(from 0 to 0.7%) is considered as variable, the other steps(key process 1, 2, and 4) are fixed. Data represent means ± SD of 10 samples of non-glutinous rice cake prepared with each manufacturing condition. Values with different superscripts within the same column are significantly different (p<0.05). *Signification at p<0.001.

3.3. Observation of Microstructure Using SEM

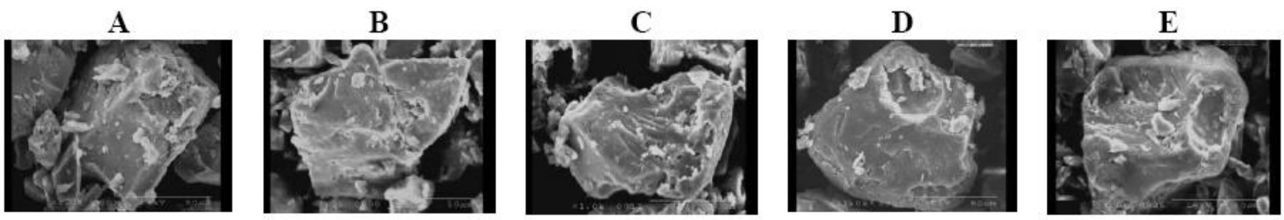

Fig. 1: SEM-Observed surfaces of non-glutinous rice cake adapted with or without RRT.

Five different manufacturing conditions are as followings; **A**: key process 1+key process 2, **B**: key process 1+key process 3, **C**: key process 1+key process 4, **D**: key process 1+key process 2+key process 3+key process 4, **E**: key process 1+key process 2+key process 3(Gluten, instead of wheat flour) key process 4

Protein is well known to affect rice starch water holding capacity and other starch gelatinization properties [16]. We prepared samples adapted with five different experimental conditions (described in detail below of the Figure 1). It was observed the rice cakes by using SEM at magnifications of x450. The observations revealed apparent differences depending on different manufacturing condition. The rice cake made with entire factors of RRT application (D) had a smooth pore-free surface that prevented moisture from evaporating, while the surface of the cake made without technology application was very rough and porous. Rice cake without RRT had small and large pores with exposed insides that likely served as pathways that allowed moisture to flow in the structure.

Table V: Effect of punching time on TPA of rice cake-Key process 4

Texture parameters	Storage time(hr)	Punching time(min)			
		2 min	7 min	13 min	20 min
Hardness(g)*	0	554.89^{ab}	525.00^{ab}	488.10^{c}	561.36^{a}
	24	735.29^{bc}	760.75^{b}	764.72^{b}	836.40^{a}
Adhesiveness	0	-315.21	-317.04	-311.30	-324.86
	24	-221.55	-284.45	-210.82	-340.95
Springiness	0	0.85	0.84	0.83	0.84
	24	0.87	0.86	0.86	0.84
Cohesiveness	0	0.65	0.66	0.68	0.68
	24	0.64	0.65	0.66	0.63
Gumminess*	0	368.85^{a}	356.28^{ab}	335.05^{b}	368.42^{a}
	24	473.97^{b}	491.94^{b}	516.01^{a}	520.17^{a}
Chewiness*	0	313.25^{a}	299.63^{ab}	279.57^{c}	309.83^{ab}
	24	414.44^{ab}	425.00^{ab}	436.14^{a}	439.11^{a}

Experimental formula were controlled to assess optimum punching time from 2 to 20 min for impacting physical force as variable, and the other steps(key process 1, 2, and 3) are fixed. Data represent means ± SD of 10 samples of non-glutinous rice cake prepared with each manufacturing condition. Values with different superscripts within the same column are significantly different (p<0.05). *Signification at p<0.001.

3.4. Degree of Retrogradation of Rice Cake

Table VI: Degree of retrogradation of rice cake with different experimental manufactruring condition

(unit: %)

A	B	C	D	E
13.13±1.79^{b}	19.28±2.19^{a}	11.37±0.24^{bc}	7.78±0.49^{c}	12.91±1.25^{b}

Each experimental manufacturing process is described below of the Fig. 1. Values with different superscripts within the same column are significantly different (p<0.05).

The degree of retrogradation of samples with different experimental condition indicated the range of 7.78 to 19.28%. The degree of retrogradation of rice cake adapted with RRT was significantly lower than that of rice cake without RRT (Table VI). In our ongoing study, A-crystalloid X-ray patterns in rice cake adapted without RRT showed a peak at 2θ=16.7 degrees, which indicates retrogradation of rice starch, but the peak was not detected in rice cake adapted with RRT at 20 ℃ up to 48 hr (data not shown). At results, we found that the best standard manufacturing procedure for RRT for non-glutinous rice cake is as followings; moisture (24%), cooling down under 65 ℃ for steamed dough, wheat starch (at least 0.2%), and punching with rotor speed of 400 rpm for 13 min. It can be assumed that the performance of the technology developed to retard starch retrogradation depends on elements such as moisture content, temperature, length of punching time, and interaction of grain starches. Further study on the mechanism of RRT is now in progress.

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