J. Food Sci. Nutr.
Vol. 3, No. 3, p. 234~240 (1998)

Effect of Thawing Methods and Storage Periods on the Quality of Frozen Cooked Rice

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Abstract

This study attempted to determine the effect of various thawing methods and storage periods on the quality of frozen cooked rice. Frozen cooked rice was thawed at four different methods, such as pressure cooking, conventional cooking, microwave heating and thawing at room temperature after 10 days, 30 days and 90 days frozen storage. We conducted a physico-chemical analysis (moisture content, dehydration rates, degree of gelatinization, color value and texture) and sensory evaluation on the frozen-thawed cooked rice. The study showed that there were no significant differences on the quality characteristics of frozen-thawed cooked rice during the storage period of 90 days. However, the thawing method of pressure cooking caused high moisture content, rapid dehydration rates, and a high degree of gelatinization on the cooked rice. Thus, the desirability for the rice diminished because of the excess moisture content and the change of appearance and texture in the rice due to the high temperature. There were similiar quality characteristics to the cooked rice after frozen-thawing whether by conventional cooking or by microwave heating and just after cooking. Thawing at room temperature also caused a significant decrease in quality characteristics.

Key words: frozen cooked rice, thawing, storage periods, quality

INTRODUCTION

Recently, demands for ready to eat or ready to cook rice products have increased due to the change of the life style. There are several types of so-called instant rices (e.g. canned, packed in retort pouches, pre-cooked dry and frozen after cooking) which can be used conveniently. The quality of frozen cooked rice is superior to other instant rices and its use has increased gradually.

There are several researches related to the quality characteristics of frozen cooked rice. Choi and Lee (1) studied the effect of freezing rate and frozen storage temperature on the retrogradation, texture and microstructure of frozen cooked rice. Kainuma (2) reported that varieties, frozen storage periods and cooking conditions affected the quality of frozen cooked rice. Kum et al. (3) studied the effect of microwave reheating on the quality of cooked rice. Lee et al. (4) predicted textural properties of cooked parboiled rice as influenced by steaming and freezing conditions.

Various factors, such as the quality of cooked rice, conditions of freezing, storage periods and thawing methods may influence the quality of frozen cooked rice. The heating of frozen cooked rice may change the gelatinization rate and moisture content of the rice. We have to investigate the effect of various factors on the quality of frozen cooked rice more thoroughly in order to understand the quality control of frozen cooked rice. The purpose of this study was to investigate the effect of various thawing methods and storage periods on the quality of frozen cooked rice.

MATERIALS AND METHODS

Rice sample preparation

Japonica type fresh milled rice (harvested in 1995, Ilpoom variety) was used for this study. A 300 g of milled rices was soaked in 450 ml distilled water for 30 min and cooked for 20 min using an automatic electric rice cooker (LG RJ-1060, 1 liter capacity), and followed by 10 min standing before removal. After 2 hour standing at room temperature, a 300 g of cooked rices was packed with polyethylene wrap in the shape of rectangular prizm (8-9×10-11×4-5 cm). The cooked rice sample was then frozen and stored at -18~-20°C. Then, frozen cooked rice was thawed at four different methods, such as pressure cooking, conventional cooking, microwave heating and thawing at room temperature after 10 days, 30 days and 90 days frozen storage. The thawing conditions were as follows: pressure cooking-heating for 7 min using a pressure cooker; conventional cooking-heating for 12 min using a conventional cooker; microwave heating-heating for 3.5 min using a microwave oven (LG MR-216M, 700 W); thawing at room temperature-5 hour standing at room temperature.

After the completion of the thawing, the sample was allowed to stand at room temperature for 30 min (sample temp.: 34~35°C) and then evaluated. The rice just cooked, followed by 30 min of standing, was used as the control sample.

Moisture contents and dehydration rates

Moisture contents of frozen-thawed cooked rice were determined by the oven drying method and dehydration rates by using the infrared moisture analyzer (5).

Degree of gelatinization

Degree of gelatinization of frozen-thawed cooked rice was determined by the glucoamylase method (6).

Color value

The color of frozen-thawed cooked rice was measured using the color difference meter (Tokyo Denshoku Co., Japan,

TC-3600) and the values of L, a, and b were recorded.

Texture measurement

The texture profile of frozen-thawed cooked rice was determined with a Texture Analyzer (TA-XT2 Stable Micro Systems, England) equipped with a 19 mm dia. cylindrical probe. The rice sample (25 g) was placed in the glass tube (25 mm height×40 mm diameter) and compressed to 30% of its original height using the TPA mode with a probe speed of 1 mm/s. Results were analyzed with the aid of a XTRAD computer program and presented as force vs time graph. Every test was replicated minimum of 5 times and mean values for each parameter calculated.

Sensory evaluation

Trained seven graduate students majoring in food & nutrition at The Catholic University of Korea evaluated the quality characterisrics of frozen-thawed cooked rice. The evaluation was conducted with thirteen samples which was composed of one control sample and twelve frozen-thawed samples from the three levels of storage periods and four different thawing methods. Panelists were provided with a set of five randomly coded samples, i.e. one control sample and four frozen-thawed samples, and instructed to rinse their mouth with water before starting and between sample evaluations. Evaluation was replicated three times and designed for each panel to be able to evaluate all the samples. Therefore, the control sample received a total of 21 evaluations and each of the frozen- thawed samples received 7 evaluations. Panelists were instructed to evaluate the samples with respect to appearance, flavor, texture and overall acceptance using a five-point category scale, in which the highest score corresponded to the highest intensity.

Statistical analysis

Data was analyzed by the ANOVA, Means and Pearson correlation procedure of Statistical Analysis System (7). Mean separation was made by the Duncan's multiple range test.

RESULTS AND DISCUSSION

Moisture contents and dehydration rates

Moisture contents of frozen-thawed cooked rice by pressure cooking and conventional cooking were significantly higher than that of the control rice, whereas moisture contents at microwave heating and thawing at room temperature were similiar to that of the control rice (Table 1). The huge increase of the moisture contents at pressure cooking might be caused by the structure of the pressure cooker in which the produced vapor cannot get out of the cooker. And moisture contents were not varied among the samples in all the thawing methods during the storage period of 90 days.

It was known that the existing form of water in cooked rice highly affects the eating quality of cooked rice (8). When the gelatinization of rice is sufficient, water does not release as easily from the cooked rice because starch and water binds well. During the storage period of 90 days, dehydration rates of the control rice and frozen-thawed cooked rice by microwave heating and conventional cooking were relatively slow, whereas those by pressure cooking and thawed at room temperature were rapid (Figs. 1, 2, 3). The rapid dehydration rates at pressure cooking and thawing at room temperature might be caused by the excess free water produced during the pressure cooking and free water due to starch retrogradation during the thawing at room temperature, respectively.

Degree of gelatinization

Degree of gelatinization of the frozen-thawed cooked rice by pressure cooking was highest among the samples, whereas the rice thawed at room temperature was lowest (Fig. 4). High temperature at pressure cooking might cause high degree of gelatinization. And there were no significant differences among the samples in each thawing method during the storage period of 90 days, so it seems that the quality of frozen-thawed cooked rice remains high when frozen in 90 days.

Color values

Color values of each sample showed no significant differences, but b value of frozen-thawed cooked rice by pressure cooking seemed a little higher than that of other thawing methods (Table 2). Shibukawa (9) and Song and Oh (10) also reported the increase of yellowness in rice by using a pressure cooker.

Texture

Texture of each frozen -thawed cooked rice was shown in Table 3 and Table 4. The palatability of cooked rice is highly affected by hardness (11). Hardness of the rice thawed at room temperature was significantly higher than that of other thawing methods and the control rice. Also hardness at pressure cooking was low as compared to that of other thawing methods and the control rice. There were no signi-

Table 1. Moisture contents of frozen preserved cooked rice at different storage periods with various thawing methods[1,2]

Frozen storage period (days) / *Thawing methods*	0 *(control)*	10	30	90
Pressure cooker	58.19 ± 0.68^{A}	67.77 ± 2.62^{Bc}	66.22 ± 1.07^{Bc}	66.07 ± 0.64^{Bc}
Conventional cooker	58.19 ± 0.68^{A}	61.63 ± 1.97^{Bd}	61.47 ± 1.53^{Bd}	60.77 ± 1.14^{ABd}
Microwave oven	58.19 ± 0.68^{A}	60.21 ± 0.26^{Ade}	59.68 ± 0.87^{Ad}	60.33 ± 1.89^{Ad}
Thawing at room temp.	58.19 ± 0.68^{A}	57.80 ± 0.81^{Ae}	57.57 ± 0.06^{Ae}	58.70 ± 1.40^{Ad}

[1]Means in rows and columns with different superscript letters are significantly different ($p<0.05$). Capital and lower case letters refer to rows and columns

[2]Values represent mean±SD

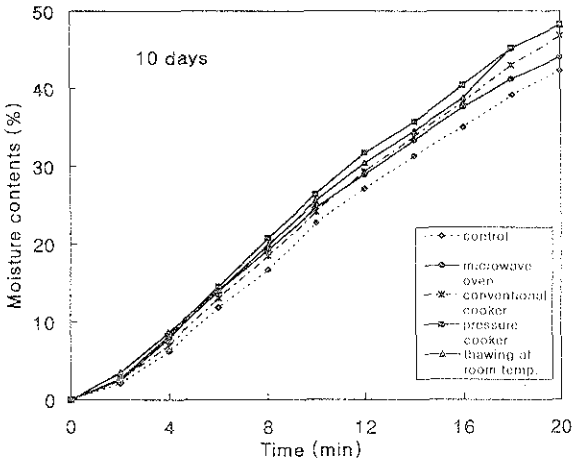

Fig. 1. Dehydration rates of 10 days frozen preserved cooked rice by various thawing methods.

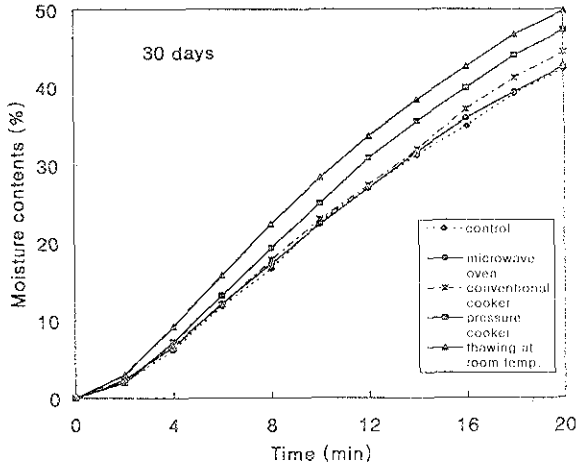

Fig. 2. Dehydration rates of 30 days frozen preserved cooked rice by various thawing methods.

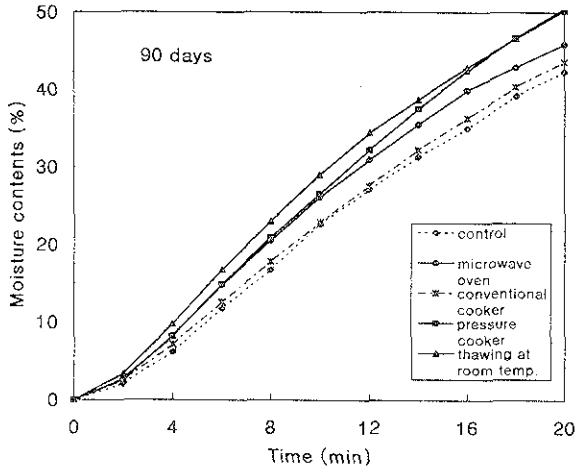

Fig. 3. Dehydration rates of 90 days frozen preserved cooked rice by various thawing methods.

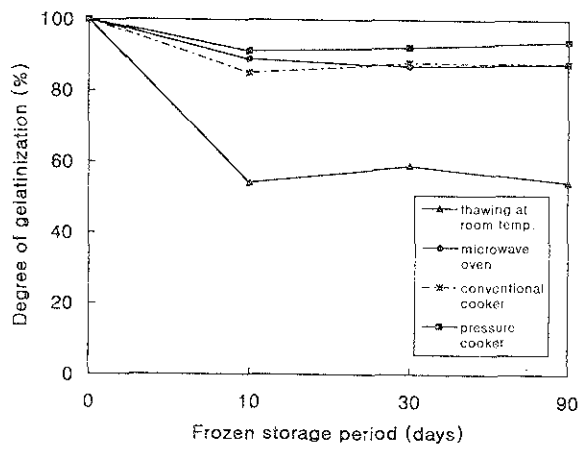

Fig. 4. Degree of gelatinization of frozen preserved cooked rice at different periods with various thawing methods.

ficant differences in hardness due to the duration of storage periods till 90 days. There were almost no significant differences among the samples in adhesiveness, but it was shown that adhesiveness at pressure cooking was higher and that thawed at room temperature was lower compared to other thawing methods and the control rice. Storage did not significantly affect adhesiveness of frozen thawed cooked rice till 90 days. Cohesiveness has an important effect on the palatability of cooked rice with hardness. Cohesiveness of frozen-thawed cooked rice by microwave heating showed a significantly higher level and that thawed at room temperature showed significantly lower level than that of other thawing methods and the control rice. It seemed that the change in inner structure of the rice thawed at room temperature was large.

Springiness of frozen-thawed cooked rice by microwave heating was significantly higher and the rice thawed at room temperature was low compared to other thawing methods during the storage period of 90 days. There were no significant differences in chewiness among each rice sample. Gumminess of frozen-thawed cooked rice by microwave heating and that thawed at room temperature was significantly higher than other thawing methods and the control rice.

Sensory characteristics

Sensory characteristics of each frozen thawed cooked rice was shown in Table 5.

In appearance, the color of frozen-thawed cooked rice by pressure cooking was a little yellowish and glossiness of the rice thawed at room temperature was less as compared to other samples during the storage period of 90 days. Moisture on surface of the rice thawed at room temperature was low and that of pressure cooking was high, and it coincided with the tendency of moisture contents of each rice sample. In flavor, there were no significant differences among the rice samples during the storage period of 90 days, except that flavor of the rice thawed at room temperature was a little inferior to other rice samples. It seemed that the texture

Table 2. Color values of frozen preserved cooked rice at different storage periods with various thawing methods[1,2]

Frozen storage period (days) / Thawing methods	0 (control)	10	30	90
Lightness (L)				
Pressure cooker	72.2 ± 0.67^{A}	72.6 ± 0.92^{Ac}	72.1 ± 2.25^{Ac}	73.0 ± 0.52^{Ac}
Conventional cooker	72.2 ± 0.67^{A}	72.2 ± 0.67^{Ac}	72.0 ± 3.06^{Ac}	72.1 ± 1.61^{Ac}
Microwave oven	72.2 ± 0.67^{A}	72.8 ± 0.95^{Ac}	73.4 ± 0.15^{Ac}	72.0 ± 1.99^{Ac}
Thawing at room temp.	72.2 ± 0.67^{A}	72.6 ± 0.64^{ABc}	73.0 ± 0.21^{ABc}	73.4 ± 0.30^{Bc}
Redness (a)				
Pressure cooker	-2.3 ± 0.12^{A}	-2.6 ± 0.10^{ABc}	-2.5 ± 0.90^{ABc}	-3.3 ± 0.25^{Bc}
Conventional cooker	-2.3 ± 0.12^{A}	-2.3 ± 0.32^{Ac}	-3.1 ± 0.35^{Bc}	-2.7 ± 0.32^{ABc}
Microwave oven	-2.3 ± 0.12^{A}	-2.5 ± 0.25^{Ac}	-2.6 ± 0.40^{Ac}	-2.4 ± 0.90^{Ac}
Thawing at room temp.	-2.3 ± 0.12^{A}	-2.2 ± 0.62^{Ac}	-2.8 ± 0.35^{ABc}	-3.3 ± 0.25^{Bc}
Yellowness (b)				
Pressure cooker	5.4 ± 0.30^{A}	5.8 ± 0.70^{Ac}	5.9 ± 0.61^{Ac}	5.8 ± 0.10^{Ac}
Conventional cooker	5.4 ± 0.30^{A}	5.1 ± 0.81^{Ac}	5.0 ± 0.46^{Ac}	4.9 ± 0.61^{Ac}
Microwave oven	5.4 ± 0.30^{A}	5.2 ± 0.20^{Ac}	5.1 ± 0.72^{Ac}	5.4 ± 0.70^{Ac}
Thawing at room temp.	5.4 ± 0.30^{A}	5.4 ± 0.64^{Ac}	5.5 ± 0.10^{Ac}	5.3 ± 0.12^{Ac}

[1]Means in rows and columns with different superscript letters are significantly different ($p<0.05$). Capital and lower case letters refer to rows and columns
[2]Values represent mean±SD

Table 3. Hardness, adhesiveness and cohesiveness of frozen preserved cooked rice at different storage periods with various thawing methods[1,2]

Frozen storage period (days) / Thawing methods	0 (control)	10	30	90
Hardness (g)				
Pressure cooker	327.4 ± 24.8^{A}	280.3 ± 41.6^{Ad}	302.0 ± 29.5^{Ad}	305.2 ± 47.8^{Ad}
Conventional cooker	327.4 ± 24.8^{A}	320.7 ± 18.4^{Ad}	311.5 ± 45.1^{Ad}	316.1 ± 19.6^{Ad}
Microwave oven	327.4 ± 24.8^{A}	335.2 ± 18.1^{Ad}	339.6 ± 37.6^{Ad}	328.2 ± 6.1^{Ad}
Thawing at room temp.	327.4 ± 24.8^{A}	439.4 ± 77.5^{Bc}	421.2 ± 2.7^{Bc}	423.9 ± 13.3^{Bc}
Adhesiveness				
Pressure cooker	150.5 ± 12.5^{A}	168.3 ± 20.1^{Ac}	161.5 ± 23.8^{Ac}	165.8 ± 10.0^{Ac}
Conventional cooker	150.5 ± 12.5^{A}	152.4 ± 13.6^{Ac}	147.8 ± 9.9^{Ac}	145.3 ± 15.7^{Ac}
Microwave oven	150.5 ± 12.5^{A}	150.3 ± 32.4^{Ac}	152.6 ± 25.0^{Ac}	158.8 ± 25.2^{Ac}
Thawing at room temp.	150.5 ± 12.5^{A}	128.5 ± 1.1^{Bc}	137.7 ± 9.5^{ABc}	143.0 ± 13.9^{ABc}
Cohesiveness				
Pressure cooker	0.414 ± 0.009^{A}	0.418 ± 0.010^{Ad}	0.421 ± 0.006^{Ad}	0.419 ± 0.015^{Acd}
Conventional cooker	0.414 ± 0.009^{A}	0.423 ± 0.022^{Ad}	0.418 ± 0.006^{Ad}	0.405 ± 0.018^{Ad}
Microwave oven	0.414 ± 0.009^{A}	0.469 ± 0.010^{Bc}	0.454 ± 0.013^{Bc}	0.461 ± 0.010^{Bc}
Thawing at room temp.	0.414 ± 0.009^{AB}	0.391 ± 0.006^{Cc}	0.400 ± 0.009^{BCc}	0.417 ± 0.007^{Acd}

[1]Means in rows and columns with different superscript letters are significantly different ($p<0.05$). Capital and lower case letters refer to rows and columns
[2]Values represent mean±SD

Table 4. Springiness, chewiness and gumminess of frozen preserved cooked rice at different storage periods with various thawing methods[1,2]

Frozen storage period (days) / Thawing methods	0 (control)	10	30	90
Springiness				
Pressure cooker	0.641 ± 0.001^{A}	0.682 ± 0.008^{Acd}	0.703 ± 0.069^{Ac}	0.702 ± 0.007^{Acd}
Conventional cooker	0.641 ± 0.001^{A}	0.677 ± 0.057^{Acd}	0.672 ± 0.010^{Acd}	0.662 ± 0.021^{Ade}
Microwave oven	0.641 ± 0.001^{A}	0.715 ± 0.007^{Bc}	0.709 ± 0.013^{Bc}	0.730 ± 0.036^{Bc}
Thawing at room temp.	0.641 ± 0.001^{A}	0.618 ± 0.052^{Ad}	0.627 ± 0.015^{Ad}	0.643 ± 0.031^{Ae}
Chewiness				
Pressure cooker	104.9 ± 19.9^{A}	99.5 ± 11.5^{Ac}	101.8 ± 9.1^{Ac}	103.3 ± 6.9^{Ac}
Conventional cooker	104.9 ± 19.9^{A}	107.6 ± 16.1^{Ac}	109.5 ± 23.7^{Ac}	103.3 ± 12.4^{Ac}
Microwave oven	104.9 ± 19.9^{A}	114.4 ± 2.6^{Ac}	114.0 ± 16.2^{Ac}	116.8 ± 14.3^{Ac}
Thawing at room temp.	104.9 ± 19.9^{A}	105.8 ± 24.4^{Ac}	104.0 ± 12.5^{Ac}	104.0 ± 10.1^{Ac}
Gumminess				
Pressure cooker	130.6 ± 15.4^{A}	127.8 ± 17.0^{Ad}	132.0 ± 8.0^{Ad}	130.1 ± 6.2^{Ad}
Conventional cooker	130.6 ± 15.4^{A}	134.9 ± 3.0^{Ad}	138.4 ± 12.0^{Ad}	132.1 ± 16.0^{Ad}
Microwave oven	130.6 ± 15.4^{A}	160.5 ± 5.1^{Bcd}	157.3 ± 18.0^{Bcd}	149.1 ± 11.6^{ABcd}
Thawing at room temp.	130.6 ± 15.4^{A}	172.1 ± 28.0^{Bc}	179.4 ± 21.3^{Bc}	167.3 ± 21.0^{Bc}

[1]Means in rows and columns with different superscript letters are significantly different ($p<0.05$). Capital and lower case letters refer to rows and columns
[2]Values represent mean±SD

Table 5. Effects of frozen storage periods and thawing methods on sensory characteristics of cooked rice[1)]

Frozen storge period (days)	0	10				30				90			
Thawing method / Characteristics	Control	Pressure cooker	Conventional cooker	Microwave oven	Thawing at room temp.	Pressure cooker	Conventional cooker	Microwave oven	Thawing at room temp.	Pressure cooker	Conventional cooker	Microwave oven	Thawing at room temp.
Appearance													
Color	3.43 ±0.53^{d}	2.24 −0.69^{c}	3.57 −0.53^{cd}	3.43 ±0.53^{b}	4.43 ±0.53^{b}	2.14 ±0.69^{c}	3.57 ±0.53^{cd}	3.57 +0.53^{cd}	4.00 ±0.82^{bcd}	2.14 ±0.69^{c}	3.57 ±0.53^{cd}	3.43 ±0.53^{d}	4.29 ±0.76^{bc}
Glossiness	3.71 ±0.49^{b}	4.29 ±0.49^{b}	3.86 ±0.69^{b}	3.43 ±0.53^{b}	1.43 −0.53^{c}	4.00 ±0.82^{b}	3.57 ±0.53^{b}	3.57 ±0.98^{b}	1.57 ±0.53^{c}	4.14 +0.69^{b}	3.43 +1.13^{b}	3.43 −0.98^{b}	1.43 ±0.53^{c}
Moist on surface	3.29 ±0.49^{c}	4.29 ±0.49^{b}	3.29 ±1.11^{c}	2.71 +0.76^{c}	1.29 ±0.49^{d}	4.14 +0.38^{b}	3.29 +0.49^{c}	2.71 ±0.49^{c}	1.57 +0.53^{d}	4.29 −0.49^{b}	3.00 ±0.82^{c}	2.57 ±0.53^{c}	1.43 ±0.53^{d}
Flavor													
Roasted nutty odor	3.71 −0.49^{b}	3.86 ±0.90^{b}	3.86 −0.69^{b}	3.86 ±0.69^{b}	3.14 ±1.07^{b}	3.86 ±0.69^{b}	3.71 ±0.49^{b}	3.57 −0.53^{b}	2.29 ±0.76^{c}	3.57 ±0.98^{b}	3.86 ±0.38^{b}	3.43 ±0.79^{b}	2.14 ±0.90^{c}
Sweety odor	3.43 ±0.53^{bc}	3.86 ±0.38^{b}	3.43 +0.79^{bc}	3.57 ±0.53^{bc}	2.71 −0.76^{cd}	3.29 +0.49^{bc}	3.00 ±1.15^{bc}	3.43 ±0.53^{bc}	1.86 ±0.69^{c}	3.00 +1.00^{bc}	3.14 −0.90^{bc}	3.14 +0.90^{bc}	2.00 +0.58^{de}
Roasted nutty taste	3.71 ±0.49^{b}	3.71 ±0.95^{b}	3.71 −0.49^{b}	3.71 +0.76^{b}	2.00 ±0.58^{c}	3.57 ±0.79^{b}	3.86 +0.69^{b}	3.29 −0.49^{b}	1.43 ±0.53^{c}	3.00 ±1.15^{b}	3.43 ±0.79^{b}	3.29 ±1.11^{b}	1.57 ±0.53^{c}
Sweety taste	3.43 ±0.79^{b}	3.71 −0.76^{b}	3.57 ±0.53^{b}	4.29 ±1.38^{b}	2.00 +0.58^{c}	3.57 +0.79^{b}	3.57 ±0.79^{b}	3.43 ±0.79^{b}	1.57 ±0.53^{c}	3.43 ±0.79^{b}	3.71 ±0.95^{b}	3.43 ±0.79^{b}	1.43 +0.53^{c}
Texture													
Hardness	3.29 ±0.48^{d}	1.71 ±0.76^{e}	3.00 ±0.58^{d}	3.43 −0.53^{d}	4.14 ±0.69^{bc}	2.00 ±0.58^{e}	3.14 ±0.69^{d}	3.43 ±0.79^{d}	4.14 ±0.38^{bc}	1.86 ±0.69^{e}	3.29 +0.49^{d}	3.57 ±0.53^{cd}	4.29 ±0.49^{b}
Irregularity of hardness	2.43 +0.53^{c}	2.29 +0.49^{c}	2.57 +0.79^{c}	2.86 ±0.69^{c}	3.86 ±0.69^{b}	2.57 ±0.53^{c}	2.57 +0.79^{c}	2.71 ±0.49^{c}	3.71 ±0.49^{b}	2.29 +0.95^{c}	2.57 ±0.53^{c}	2.57 ±0.53^{c}	3.86 +0.69^{b}
Stickiness	3.29 ±0.76^{bcd}	4.00 +0.82^{b}	3.00 ±0.82^{cd}	2.86 ±0.69^{cd}	1.29 ±0.49^{e}	3.57 ±0.53^{bcd}	2.71 ±0.76^{d}	3.14 ±0.69^{bcd}	1.43 ±0.79^{e}	3.71 +0.49^{bc}	3.29 +0.76^{bcd}	3.00 ±0.82^{cd}	1.71 ±0.76^{e}
Inner moisture	2.86 ±0.69^{cd}	4.14 ±0.38^{b}	3.14 ±0.69^{c}	3.00 ±0.58^{c}	2.14 +0.69^{de}	4.14 +0.69^{b}	3.00 ±0.82^{c}	3.00 ±0.58^{c}	2.00 ±0.82^{e}	4.00 ±0.58^{b}	3.14 ±0.69^{c}	2.86 ±0.69^{cd}	2.00 +0.82^{e}
Ease of swalling	3.43 ±0.53^{c}	4.43 +0.53^{b}	3.57 ±0.53^{c}	3.43 ±0.79^{c}	2.29 ±0.49^{d}	3.57 ±0.53^{c}	3.43 +0.53^{c}	3.43 +0.53^{c}	2.00 ±0.58^{d}	3.86 +0.90^{bc}	3.71 ±0.49^{c}	3.43 ±0.53^{c}	2.43 ±0.53^{d}
Overall acceptance	3.57 ±0.53^{bcd}	3.57 ±0.79^{cd}	3.86 ±0.69^{bcd}	3.86 +0.69^{bcd}	1.57 −0.53^{e}	3.00 ±0.82^{d}	3.57 ±0.53^{bcd}	4.00 ±1.00^{bc}	1.57 ±0.53^{e}	3.29 ±0.76^{bcd}	3.71 ±0.95^{bcd}	4.14 ±0.69^{b}	1.43 ±0.53^{e}

[1)]Means with different superscript letters within the same row are significantly different ($p<0.05$). As the value increases 1 to 5, the intensity of sensory characteristics increases.

Table 6. Correlation coefficients between each sensory characteristic

	Color	Gloss-ness	Moist on surface	Roasted nutty odor	Sweety odor	Roasted nutty taste	Sweety taste	Hard-ness	Irregularity of hardness	Stick-iness	Inner moisture	Ease of swalling	Overall accept-ance
Color	-	-	-	-	-	-	-	-	-	-	-	-	-
Glossiness	-0.593***	-	-	-	-	-	-	-	-	-	-	-	-
Moist on surface	-0.673***	0.719***	-	-	-	-	-	-	-	-	-	-	-
Roasted nutty odor	-0.269*	0.460***	0.425***	-	-	-	-	-	-	-	-	-	-
Sweety odor	-0.237*	0.499***	0.340**	0.425***	-	-	-	-	-	-	-	-	-
Roasted nutty taste	-0.332**	0.600***	0.458***	0.581***	0.591***	-	-	-	-	-	-	-	-
Sweety taste	-0.409***	0.625***	0.561***	0.504***	0.609***	0.646***	-	-	-	-	-	-	-
Hardness	0.729***	-0.570***	-0.701***	-0.394***	-0.264*	-0.335*	-0.415***	-	-	-	-	-	-
Irregularity of hardness	0.479***	-0.642***	-0.557***	-0.287**	-0.402***	-0.424***	-0.556***	0.504***	-	-	-	-	-
Stickiness	-0.616***	0.682***	0.636***	0.409***	0.423***	0.461***	0.588***	-0.600***	-0.523***	-	-	-	-
Inner moisture	-0.560***	0.615***	0.650***	0.287*	0.350**	0.436***	0.472***	-0.638***	-0.500***	0.665***	-	-	-
Ease of swalling	-0.409***	0.690***	0.703***	0.370***	0.465***	0.510**	0.570***	-0.551***	-0.512***	0.570***	0.512***	-	-
Overall acceptance	-0.303**	0.599***	0.433***	0.353***	0.357***	0.567***	0.516***	-0.308**	-0.483***	0.525***	0.360***	0.457***	-

*, **, ***Significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively

Table 7. Correlation coefficients between sensory characteristics and mechanical measurements

Mechanical measurements	Sensory characteristics						
	Color	Glossiness	Moist on surface	Hardness	Stickiness	Inner moisture	Overall acceptance
Moisture contents	-0.927***	0.715**	0.867***	-0.956***	0.764**	0.935***	0.356
Lightness (L)	0.198	-0.422	-0.373	0.256	-0.326	-0.298	-0.434
Redness (a)	0.110	0.111	-0.054	0.082	0.042	-0.014	0.260
Yellowness (b)	-0.661*	0.157	0.391	-0.565*	0.256	0.477	-0.238
Hardness	0.802***	-0.984***	-0.935***	0.836***	-0.955***	-0.88***	-0.855***
Adhesiveness	-0.903***	0.852***	0.872***	-0.863***	0.896***	0.877***	0.633*
Cohesiveness	-0.161	0.400	0.148	-0.057	0.345	0.185	0.644*

*, **, ***Significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively

of frozen-thawed cooked rice by conventional cooking and microwave heating was similiar to the texture of the rice just cooked. The rice thawed by pressure cooking was softer, stickier and had much more inner moisture as compared to that of other thawing methods. And there were no significant differences in texture of each rice sample during the storage period of 90 days.

Overall acceptance of the rice thawed at room temperature was significantly lower during all the storage periods that were studied. Although there were no significant differences except thawing at room temperature, overall acceptance at microwave heating tended to be high and those at pressure cooking to be low. The decrease in the desirability of the rice thawed by pressure cooking may be caused by the excess moisture content and the change of appearance and texture in the rice due to the high temperature.

Correlation between each sensory characteristic was shown in Table 6. Although correlation between overall acceptance and other sensory characteristics was not so high, overall acceptance was positively correlated with glossiness, roasted nutty odor, roasted nutty tatste, sweety taste and stickiness. Besides, glossiness was positively correlated with moist on surface and hardness was negatively correlated with moist on surface and inner moisture. Correlation between sensory characteristics and mechanical measurements was shown in Table 7. Sensory hardness and stickiness were highly correlated with instrumental hardness and adhesiveness, and they were also highly correlated with moisture contents. Juliano et al. (12) reported that the harder rice sample had lower water content regardless of cooking method. Kim et al. (13) also reported that sensory hardness and inner moisture were correlated with moisture contents. This study showed that well gelatinized, soft rice would be palatable, whereas overall acceptance had a high negative correlation with the hardness of the rice.

ACKNOWLEDGEMENTS

This work was partially supported by the Miwon Research Institute of Korean Food & Dietary Culture.

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(Received July 31, 1998)