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Sensory Characteristics and Consumer Acceptance of Frozen Cooked Rice by a Rapid Freezing Process Compared to Homemade and Aseptic Packaged Cooked Rice

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ABSTRACT: Descriptive analysis and consumer acceptance tests were conducted with frozen (FCR), homemade (HCR), and aseptic-packaged (ACR) cooked rice products from two cultivars－IM and SD. FCR was prepared using a rapid freezing process, which may provide consumers with a quality similar to that of HCR. The intensity of the flavors of roasted, glutinous rice, rice cake, and rice starch and the textures of glutinousness, moistness, chunkiness, adhesiveness, and squishiness were all greater in the FCR as compared to the HCR and ACR ($p<0.05$) in IM and SD cultivars. The differences in sensory characteristics between the FCR and ACR were larger than the equivalent differences between the FCR and HCR. Overall consumer acceptance ratings for FCR in overall aspect, appearance, aroma, and texture were not significantly different compared to those for HCR ($p>0.05$); however, in most cases these factors showed significant differences when compared with ACR ($p<0.05$). From partial least square regression analysis, cooked rice was positively related to sweet, transparency, glossiness, roasted, glutinousness, chunkiness, moistness, glutinous rice, adhesiveness, rice shape, rice starch, and squishiness attributes but negatively related to raw rice, old rice, old rice aroma, a particle feeling, off-aroma, white color, scatteredness, slickness, size of cooked rice, and firmness attributes.

Keywords: cooked rice, rapid freezing process, descriptive analysis, consumer acceptance

INTRODUCTION

Dietary life in Korea has changed drastically over the past 20 years; people now consume less rice, traditionally a main staple, and more bread and processed foods (1-3). In addition, the growing number of small family units composed of one or two members has resulted in a decreased amount of time spent cooking at home (4). Although many single or small family units do not want to spend the extra time required to cook rice, they would consume cooked rice more frequently if it could be prepared more easily (2). This phenomenon has generated higher demand for precooked and ready-to-cook food products because consumers seek convenience. To meet consumers' needs, retort and drying technologies have been applied to ready-to-cook rice products that can be kept at room temperature for long periods of time (4,5).

As Korea's economy has developed, consumers have demanded higher-quality food products and easier means of storing them. Processed frozen foods, which are easy to cook and last for long periods of time, are an appropriate way to meet their expectations. Freezing processes have been applied mainly to raw products (e.g., vegetables, fish, and meats) to improve food safety, convenience, and quality (6,7). While Korean food companies have launched many frozen dumpling, meat, and seafood products on the market as side dishes, the freezing processes have not been widely applied to cooked rice products (8,9). However, the desire for homemade-style cooked rice is common among consumers, especially in small families who do not want to waste time and energy cooking their own rice. Frozen cooked rice may come closer to the sensory characteristics of home-cooked rice than the aseptic packaged cooked rice due to the use of a similar manufacturing process. A severe heat treatment is required in the production of the aseptic packaged cooked rice as all micro-organisms must be killed (8). This heat treatment affects the quality of the cooked rice, making it less like

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home-cooked rice. The freezing of cooked rice may be a way of providing rice to the consumer that is more similar in quality to home-cooked rice than the aseptic, packaged cooked rice.

The rapid freezing process might be a suitable freezing processing technique to create a similar quality of cooked rice to homemade rice. Rapid freezing generates smaller and uniform ice crystals, which are directly related to the quality of frozen food products (6). This process might minimize the deterioration of texture, the oxygen contact, and the dehydration that typically occurs during the freezing period (10). Few studies have researched the process of freezing cooked rice; however, samples were frozen at $-18^{\circ}C$ using a general freezer (8,9). To the author's knowledge, no researchers have applied the rapid freezing process, which is a commercial freezing method to cooked rice products, measured changes in sensory characteristics, and compared consumer acceptance of cooked rice products produced by different processing methods. The market for frozen cooked rice was 40 billion won (approximately $ 40 million) in 2008, and is growing steadily (11). Consumers are proving to have a greater interest in frozen cooked rice as it has greater similarities in quality to home-cooked rice. Therefore, the objectives of this study were 1) to characterize the descriptive sensory characteristics of the frozen cooked rice (FCR) compared with homemade cooked rice (HCR) and aseptic-packaged cooked rice (ACR), 2) to measure consumer acceptance of the FCR and compare the acceptability to that of FCR and HCR, and 3) to investigate what descriptive attributes are influenced the acceptability for cooked rice.

MATERIALS AND METHODS

Selection of rice cultivar and cooked rice preparation

Four rice cultivars were initially selected for this research labeled as IM, CC, BR, and SD. Sensory scientists and researchers who have researched and developed cooked rice products for at least two years tested the four rice cultivars to select the best ones for the present study. IM is one of the rice cultivars used for home cooking and frozen rice products. CC is a well-known cultivar for home cooking. BR is less expensive and has higher productivity than other cultivars. Finally, SD is the most widely used rice cultivar in Korea for commercial frozen rice products. After tasting the FCR for each cultivar, the research panel group reached a consensus by selecting IM and SD for this study. The HCR was prepared using a rice cooker (CR-1052G, Cucu Homesys, Yangsan, Korea), a method Koreans typically use to cook rice at home. Tap water was used to wash 1,000 grams of rice three times. The washed rice was then soaked in spring water (Sparkle, Sparkle Co. Ltd., Cheonan, Korea) for an hour to improve its quality once cooked (12). Additional water (1,371.39 g) was added so that the moisture content of the HCR was approximately 64% after cooking. The additional amount of water needed to cook the rice was calculated based on the following formula:

A g (Amount of water that the rice absorbed) = (Weight of 1,000 g of rice after one hour in water) g $-$1,000 g

1,371.39 g$-$A g=(Amount of water that needs to be added) g

The soaked rice and the additional amount of water (Sparkle, Sparkle Co. Ltd.) calculated from the formula were both placed into the rice cooker and the automatic cooking option was applied. The cooked rice was kept in the rice cooker for 15 minutes after it finished cooking. In the rice cooker, the HCR was mixed, with the exception of the bottom portion. The HCR was then placed in a bowl and served to the panelists. The FCR was prepared using the same process as the HCR. After being cooked in the rice cooker, 210 g of cooked rice was put into the plastic bowl and frozen in a rapid freezer (Blast chiller, IRINOX, Treviso, Italy) at $-40^{\circ}C$ for one hour. The FCR was packaged in plastic wrap and cooking foil and kept at $-18^{\circ}C$ for two weeks. The FCR was re-heated in a microwave (RE-C24RWS, Samsung Electronics, Seoul, Korea) for three minutes at 700 W and served to the panelists. The moisture content of the FCR was approximately 63%. The ACR was prepared at a pilot plant facility specifically designed as a smaller version of the commercial facilities used to mass produce ACR. The only difference from commercially available ACR is the rice cultivar in the sample. The internal moisture content of the ACR was approximately 64%. The ACR was heated for two minutes using a microwave at 700 W (RE-C24RWS, Samsung Electronics) and served to the panelists.

Descriptive analysis

Descriptive analysis for three different cooked rice samples of two cultivars, IM and SD, was conducted by 10 trained panelists (married females, ages 38 to 51). Each panelist had already finished a three-month basic training to become a descriptive analysis panel. The panelists had at least five years of experience in modified quantitative descriptive analysis (QDA) with various food products. The 15-point scale was labeled so that 1=threshold, 3=weak, 7=moderate, 11=strong, and 15=very strong, unlike the original QDA®. The intensity descriptors helped the panelists rate various sensory attributes of the samples and provided guidelines for the evaluation. Panelists were members of a fixed panel group for a company that evaluates cooked rice; they had conducted several descriptive analysis studies for the various types of cooked rice products over the past three years. Panelists received eighteen hours of training to evaluate cooked rice. To create a broad attribute pool for cooked rice, panelists generated a number of attributes, narrowed down these attributes, discussed their definitions, and determined the best ways to evaluate each attribute for the HCR, FCR, and ACR of the two cultivars. After four hours of training, the final definitions of the attributes and evaluative criteria for each attribute were decided based on a consensus among the panelists. Over two hours, panelists discussed and se-

Table 1. Definition, evaluation process, and evaluation timing of 27 descriptive sensory attributes of frozen, homemade, and aseptic-packaged cooked rice

Modality	Attribute	Definition	Evaluation process	Evaluation timing
Aroma	Roasted	Aroma related to roasted rice	Highest intensity of roasted aroma when smelling cooked rice sample	Before eating
	Cooked rice	Aroma related to cooked rice	Highest intensity of cooked rice aroma when smelling cooked rice sample	Before eating
	Old rice	Aroma related to old rice	Highest intensity of old rice aroma when smelling cooked rice sample	Before eating
	Off-aroma	Aroma not related to cooked rice	Highest intensity of off-aroma when smelling cooked rice sample	Before eating
Taste & flavor	Sweet	Sweet taste	Highest intensity of sweet taste when chewing cooked rice sample	Middle of chewing period
	Roasted	Flavor related to roasted rice	Highest intensity of roasted aroma when chewing cooked rice sample	Middle of chewing period
	Burnt	Flavor related to burnt rice	Highest intensity of burnt aroma when chewing cooked rice sample	Middle of chewing period
	Glutinous rice	Flavor related to cooked glutinous rice	Highest intensity of glutinous rice when chewing cooked rice sample	Middle of chewing period
	Rice cake	Flavor related to rice cake	Highest intensity of rice cake when chewing cooked rice sample	Middle of chewing period
	Raw rice	Flavor related to raw rice	Highest intensity of raw rice when chewing cooked rice sample	Middle of chewing period
	Rice starch	Flavor related to rice starch	Highest intensity of rice starch when chewing cooked rice sample	Middle of chewing period
	Old rice	Flavor related to old rice	Highest intensity of old rice when chewing cooked rice sample	Middle of chewing period
Texture	Firmness	Force to deform cooked rice particles	Intensity of firmness when chewing the sample using front teeth	First chewing
	Glutinousness	Stickiness of cooked rice	Intensity of glutinousness when chewing using molars	Initial chewing period
	Moistness	Moisture content when chewing cooked rice chunk	Amount of moisture from the sample before swallowing	Middle of chewing period
	Chunkiness	Formation of mass when chew chunk of cooked rice	Intensity of chunkiness when chewing 2~3 times using molars	Between initial and middle of chewing period
	Cohesiveness	Amount of force to go back to the original shape when chew the cooked rice	Speed of re-shape of cooked rice when press the sample to palate the using tongue	Before first chew
	Adhesiveness	Adhesiveness of cooked rice to the surface of the mouth	Intensity of adhesiveness of cooked rice on the lips	Before first chew
	Scattteredness	Dispersion of cooked rice particles	Intensity of scattering cooked rice when chewing a chunk of cooked rice	Entire chewing period
	Squishiness	Squishiness of cooked rice particles	Intensity of squishiness of cooked rice in the mouth	Entire chewing period
	Particle feeling	Amount of left-over particles after shallow cooked rice	Feeling of left-over rice particles after swallowing cooked rice sample	After swallowing cooked rice
Appearance	Glossiness	Shininess of cooked rice surface	Measure the intensity of shininess of cooked rice surface under lightening box	In the light box
	Transparency	Transmission of light through cooked rice particle	Measure the intensity of transmission of light through cooked rice particle under lightening box	In the light box
	Rice shape	Intactness of cooked rice particles	Measure the intensity of intactness of cooked rice particles under lightening box	In the light box
	Slickness	Smoothness of cooked rice surface	Measure the intensity of smoothness of cooked rice surface under lightening box	In the light box
	Size of cooked rice	Size of a rice particle	Measure the intensity of size of a rice particle under lightening box	In the light box
	White color	Degree of white color	Measure the intensity of white color under lightening box	In the light box

lected proper attributes from the cooked rice attribute pool for IM and SD cultivars: four attributes for aroma, eight attributes for taste/flavor, nine attributes for texture, and six attributes for appearance (Table 1). Panelists had a separate training for IM and SD after they determined the attributes. Panelists underwent rank-order training for two hours for IM in which they ranked the samples based on the intensity of each attribute. Throughout this training, panelists became familiar with the samples' differences according to 27 attributes. After the rank-order training, panelists received an additional two-hour training to rate the intensity for each attribute for IM. Panelists rated the intensities of each attributes for each sample and reviewed their ratings to minimize variations in the intensities of each attribute. A 15-point category scale was used for the training. If there was a discrepancy in the attribute ratings among a specific sample, panelists were asked to re-taste the sample and discuss those attributes. Three replications of the final evaluations were conducted over two hours. The same procedure was conducted for SD cultivar after the training and evaluation of IM cultivar.

Panelists were served three cooked rice samples (FCR, HCR, and ACR) in randomized order and rated the intensity of each attribute using a 15-point category scale for each cultivar. Seventy grams of each type of cooked rice was placed in a plastic cup. The plastic cups were then kept in a warmer to maintain a sample temperature of 70°C. The plastic cups were put into a thermos lunch box (AL-500, Woonam Industry, Seoul, Korea) to minimize the temperature change of the samples prior to the commencement of the panel training. Panelists used chopsticks to taste samples, were asked to swallow the samples after tasting, and instructed to rinse their mouths with bottled spring water (Sparkle, Sparkle Co. Ltd.) before and between each sample. The method of simultaneous scale presentations was used to allow panelists to compare the intensity of each attribute of the samples (13). Panelists evaluated the attributes in a given order: aroma, taste/flavor, texture, and appearance. The final evaluations were conducted in individualized booths under red lighting to minimize the influence of color. Samples were placed in a light box (Superlight, Boteck, Siheung, Korea) under a daylight setting to measure their appearance attributes. Data were collected using a computerized sensory data collection system (SensMine, Sensometrics, Bucheon, Korea). The temperature in the booth area was approximately 24°C.

Consumer acceptance test

The consumer acceptance test for the HCR, FCR, and ACR for IM and SD was conducted in two separate sessions. One session was for the HCR, FCR, and ACR of IM cultivar conducted by 51 married females, ages 25 to 49 that lived in the Seoul and Gyonggi-do areas. The second session was for the HCR, FCR, and ACR of SD cultivar conducted by 50 married females but of the same age group and region as the previous session. Consumers were recruited from random text messages and e-mails from a company database for consumer tests. Before the commencement of the test, consumers were instructed for 10 minutes regarding the use of the 9-point hedonic scale, how samples would be presented, and how to taste samples. Consumers were also instructed to rinse their mouths with bottled spring water (Sparkle, Sparkle Co. Ltd.) before and between the samples. During the test, consumers rated the overall acceptability of each sample, as well as their level of acceptance in terms of appearance, aroma, and texture using the 9-point hedonic scale with a descriptor for each category (14). Approximately 210 grams of each sample was served in a white rice bowl to six consumers seated at each table. Each consumer used disposable spoons to transfer the cooked rice from the bowl into her paper cup and then tasted the sample. Paper cups and spoons were changed for every sample. Each sample was presented every 10 minutes to provide enough time for evaluation. Sample presentations were randomized using Williams' design of three samples to minimize the carry-over effect among samples (15). Consumers were strictly prohibited from talking and using their cell phones during the test. The consumer acceptance test was conducted in an open area under florescent lighting and controlled temperature (24°C).

Data analysis

The ratings from the descriptive analysis were analyzed using analysis of variance (ANOVA) with Duncan's post-hoc analysis to determine whether there were significant differences among FCR, HCR, and ACR for each cultivar at $p=0.05$ using the Statistical Package for Social Sciences (SPSS version 12, IBM Corporation, Endicott, NY, USA). Replication, panelist, and sample were used as a source of variation for the ANOVA model for each attribute. One-way ANOVA and Duncan's post-hoc analysis also applied to the data from the consumer acceptance test to find out significant differences among three samples for each cultivar. The agglomerative hierarchical clustering analysis (AHC) was conducted to segment consumers based on their acceptance ratings of FCR, HCR, and ACR for each cultivar using XLSTAT (version 2012, Addinsoft, Paris, France). Partial least squares regression (PLSR) was conducted to determine which descriptive attributes were important factors in determining consumer acceptance of three types of cooked rice from two rice cultivars using XLSTAT (version 2012, Addinsoft).

RESULTS AND DISCUSSION

According to the reproducibility of panelists, 22 out of the 27 attributes were reproducible ($p>0.05$). The roasted aroma, cooked rice aroma, burnt flavor, cohesiveness, and rice shape were significantly different across the three evaluations ($p<0.05$). This meant that panelists were not adequately trained to show reproducibility in the evaluation of those five attributes. Therefore, these five attributes were removed from further analyses. The panelists contributed a significant source of variation, which is common in descriptive analysis. One reason for this variation was that the panelists did not use the same parts of the scale, which is a common theme yet has not been considered a problem in descriptive analysis (16). Samples were also a major source of variation ($p<0.05$) after considering the effects of replication and the panelists on the ANOVA model.

The mean intensity and mean separation for 22 attributes of IM cultivar are presented in Table 2. All the attributes were statistically significant among the samples of all three types of cooked rice ($p<0.05$). There was no difference in aroma attributes between FCR and HCR. The FCR showed significantly higher intensities in the roasted, glutinous rice, rice cake and rice starch flavors ($p<0.05$). To date no research has been conducted to analyze the chemical compounds for FCR. Varying amounts and combinations of the chemical compounds were found between rice cooked in a pressure cooker, in an electric cooker, and a pot (*dookbeki*) (12). Therefore, changes in the intensity of many flavor attributes might be related to the moisture evaporated when FCR was re-heated in the microwave. Among the texture characteristics of FCR, the glutinousness, moistness, chunkiness, adhesiveness, and squishiness were significantly increased ($p<0.05$), while firmness, cohesiveness, and scatteredness were decreased significantly ($p<0.05$) compared to the HCR. Contraction in the FCR was found when using a microwave oven, and this was intensified as samples were kept for a longer time in the freezer (17). This physical change in the structure of cooked rice is expected to be directly related to the texture of cooked rice. In addition, texture attributes such as chunkiness, cohesiveness, and squishiness, which increased as in soft-boiled cooked rice, were possibly due to the breakdown of the cells when the HCR was frozen by the rapid freezing process (12). Although the rapid freezing process minimizes the size of the water crystal, water crystals may influence the texture of cooked rice to some degree. The intensity of all the appearance characteristics in the FCR was significantly lower than those in the HCR ($p<0.05$). The lower intensities of glossiness, transparency, rice shape, and slickness would be due to the contraction of cooked rice particles during microwave heating. The white color attribute was lower in FCR ($p<0.05$) due to the restoration of starch molecules as aging happens (8).

When FCR was compared to ACR, more drastic

Table 2. Mean attribute intensities and results of mean separation test of 22 attributes of IM cultivar[1)]

Modality	Attribute	IM		
		Frozen cooked rice	Home-made cooked rice	Aseptic-packaged cooked rice
Aroma	Old rice	$1.13±0.73^b$	$1.10±0.55^b$	$3.83±1.37^a$
	Off-aroma	$1.03±0.18^b$	$1.37±0.81^b$	$2.27±1.64^a$
Taste/flavor	Sweet	$8.13±1.01^a$	$8.20±1.19^a$	$5.37±0.85^b$
	Roasted	$9.67±0.80^a$	$8.13±0.86^b$	$5.20±1.13^c$
	Glutinous rice	$6.20±1.42^a$	$4.33±1.37^b$	$1.77±0.82^c$
	Rice cake	$9.13±1.46^a$	$7.30±2.41^b$	$5.23±1.77^c$
	Raw rice	$1.13±0.73^b$	$1.23±0.94^b$	$3.53±1.22^a$
	Rice starch	$5.23±2.13^a$	$3.83±2.36^b$	$2.43±1.68^c$
	Old rice	$1.03±0.18^b$	$1.13±0.35^b$	$3.73±1.20^a$
Texture	Firmness	$4.77±0.73^c$	$6.77±0.82^b$	$8.40±0.81^a$
	Glutinousness	$9.40±0.86^a$	$7.83±0.87^b$	$4.97±0.72^c$
	Moistness	$9.27±0.87^a$	$7.40±0.67^b$	$5.03±0.56^c$
	Chunkiness	$9.20±0.96^a$	$7.30±0.95^b$	$4.57±0.77^c$
	Adhesiveness	$8.10±1.54^a$	$6.27±1.55^b$	$4.07±1.08^c$
	Scattteredness	$3.43±1.17^c$	$5.73±1.46^b$	$8.40±0.81^a$
	Squishiness	$7.70±1.42^a$	$2.53±1.53^b$	$3.83±1.26^c$
	Particle feeling	$2.00±0.59^b$	$2.53±1.01^b$	$4.80±1.16^a$
Appearance	Glossiness	$7.63±0.93^b$	$9.23±1.01^a$	$5.30±0.65^c$
	Transparency	$6.73±1.31^b$	$8.07±1.66^a$	$4.50±1.01^c$
	Slickness	$4.67±0.84^c$	$6.97±1.25^b$	$8.67±1.12^a$
	Size of cooked rice	$5.23±1.28^c$	$7.10±1.21^b$	$8.63±1.07^a$
	White color	$6.10±0.96^c$	$7.33±1.42^b$	$9.20±1.03^a$

[1)]Means with the same letter within the row are not significantly different at p=0.05 by Duncan's post-hoc analysis.

changes in the intensity of sensory characteristics were found (Table 2), owning to the differences in the processing methods and the more severe heat treatment involved in the processing of the ACR that is designed to kill all the microorganisms (8). The aroma intensities of the FCR were significantly lower for the old rice and the off-aroma than those in ACR ($p<0.05$). To date, no published studies exist about the off-aroma in ACR. The off-aroma might be generated due to the different processing method in comparison with HCR and FCR. The taste/flavor intensities of sweet, roasted, glutinous rice, rice cake and rice starch were significantly higher in FCR than in ACR ($p<0.05$). However, the flavor intensities of raw rice and old rice were significantly lower ($p<0.05$). The texture intensities of glutinousness, moistness, chunkiness, adhesiveness, and squishiness were significantly higher in FCR than in ACR ($p<0.05$); while the texture intensities of firmness, and scatteredness were significantly lower ($p<0.05$). In appearance, FCR showed significantly higher glossiness and transparency than ACR, and lower slickness, size, and white color ($p<0.05$).

The mean consumer acceptance ratings for IM are presented in Table 3. The differences in overall acceptance ($p=0.166$) and acceptance of appearance ($p=0.686$) among FCR, HCR, and ACR were not statistically significant. The acceptance of aroma and texture were significantly lower in ACR ($p<0.05$). Although the ratings were not significantly different among the three samples, ACR had the lowest acceptance overall and was lowest for aroma and texture. Significant differences in sensory characteristics were found in the descriptive analysis but no difference was observed in the consumer acceptance ratings between the FCR and HCR. Furthermore, the standard deviation of the FCR was larger than both HCR and ACR, inferring that consumers varied in their liking for the FCR and may therefore be divided into two groups, those who liked or disliked the FCR. Consumers were, therefore, grouped together based on their overall acceptance of the three samples of the IM cultivar in order to investigate this issue by AHC (Table 4). Each cluster characterizes the evaluation pattern for one of the three samples. Cluster 1 is made up of consumers who do not like FCR. Consumers in cluster 2 like cooked rice in general, but also liked HCR and FCR more than ACR. Cluster 3 contains the consumers who liked only FCR. This cluster analysis supports the evidence that consumers have different preferences regarding the three types of cooked rice, rather than all being in agreement. The similarity in overall acceptance ratings for FCR and HCR were merely due to the offset of the ratings in each cluster. Therefore, the results from the cluster analysis are comparable to the differences in sensory characteristics between FCR and HCR.

The mean intensity and mean separation of 22 attributes of SD cultivar are presented in Table 5. The intensity rating patterns of the three samples of SD were very close to the patterns for IM. All the attributes were statistically significant among the three types of cooked rice samples ($p<0.05$). No difference was observed in aroma attributes between FCR and HCR. FCR showed significantly higher intensities for roasted, glutinous rice, rice cake, and rice starch flavors ($p<0.05$). Among the texture characteristics of FCR, glutinousness, moistness, chunkiness, adhesiveness, and squishiness were significantly increased ($p<0.05$), while firmness, cohesiveness, and scatteredness were significantly decreased ($p<0.05$) compared to HCR. The intensity of all the appearance characteristics were significantly lower in FCR than in HCR ($p<0.05$). When FCR was compared to ACR, the SD cultivar also demonstrated greater changes in the intensity of its sensory characteristics (Table 5). The mean separation patterns were identical when com-

Table 3. Mean acceptance ratings, standard deviations, and results of mean separation tests of overall, appearance, aroma, and texture for IM cultivar[1)]

Sample	Overall	Appearance	Aroma	Texture
Frozen cooked rice	5.82 ± 1.65^a	5.75 ± 1.61^a	6.20 ± 1.30^a	5.88 ± 1.45^a
Home-made cooked rice	5.92 ± 1.26^a	5.69 ± 1.45^a	6.20 ± 1.23^a	5.80 ± 1.44^a
Aseptic-packaged cooked rice	5.49 ± 1.14^a	5.90 ± 1.24^a	5.29 ± 1.17^b	5.31 ± 1.33^b
p-value	0.166	0.686	0.000	0.070

[1)]Means with the same letter within the column are not significantly different at p=0.05 by Duncan's post-hoc analysis.

Table 4. Agglomerative hierarchical clustering analysis (AHC) from the results of consumer acceptance tests for IM cultivar by 51 consumers[1)]

Cluster	Subject	FCR	HCR	ACR
1	20	4.20±1.24	5.45±1.23	5.35±1.14
2	23	6.96±0.82	6.83±0.65	5.87±1.14
3	8	6.63±0.74	4.50±0.53	4.75±0.71

[1)]FCR, HCR, and ACR means frozen cooked rice, homemade cooked rice, and aseptic-packaged cooked rice, respectively.

Table 5. Mean attribute intensities and results of mean separation tests of 22 attributes of SD cultivar[1)]

Modality	Attribute	SD		
		Frozen cooked rice	Home-made cooked rice	Aseptic-packaged cooked rice
Aroma	Old rice	1.00±0.00[b]	1.00±0.00[b]	3.87±1.22[a]
	Off-aroma	1.13±0.51[b]	1.50±1.01[b]	2.17±1.32[a]
Taste/flavor	Sweet	8.07±1.28[a]	8.53±0.94[a]	5.33±0.92[b]
	Roasted	9.63±1.03[a]	8.10±1.12[b]	5.20±1.06[c]
	Glutinous rice	6.40±1.54[a]	4.50±1.74[b]	2.07±1.01[c]
	Rice cake	9.40±1.28[a]	7.37±2.40[b]	5.03±1.63[c]
	Raw rice	1.03±0.18[b]	1.10±0.40[b]	3.47±0.94[a]
	Rice starch	5.33±1.94[a]	3.53±2.06[b]	2.00±0.95[c]
	Old rice	1.03±0.18[b]	1.07±0.37[b]	3.57±0.86[a]
Texture	Firmness	4.53±0.82[c]	6.90±1.03[b]	8.33±1.15[a]
	Glutinousness	9.47±1.17[a]	7.87±1.07[b]	4.90±0.71[c]
	Moistness	9.17±1.05[a]	7.50±0.82[b]	4.93±0.69[c]
	Chunkiness	9.13±1.04[a]	7.23±0.97[b]	4.57±0.73[c]
	Adhesiveness	8.10±1.79[a]	6.37±1.67[b]	4.07±1.11[c]
	Scattteredness	3.67±1.09[c]	5.57±1.36[b]	8.33±0.88[c]
	Squishiness	7.53±1.61[a]	5.50±1.59[b]	3.63±1.40[c]
	Particle feeling	2.07±0.78[b]	2.37±0.96[b]	4.57±1.19[a]
Appearance	Glossiness	7.53±1.22[b]	9.27±0.87[a]	5.27±1.05[c]
	Transparency	6.70±1.29[b]	8.03±1.52[a]	4.33±1.03[c]
	Slickness	4.50±0.78[c]	6.90±0.92[b]	8.70±0.88[a]
	Size of cooked rice	5.23±1.50[c]	7.40±1.00[b]	8.83±0.87[a]
	White color	6.27±1.05[c]	7.20±1.49[b]	9.27±1.05[a]

[1)]Means with the same letter within the row are not significantly different at p=0.05 by Duncan's post-hoc analysis.

Table 6. Mean acceptance ratings, standard deviations, and results of mean separation tests of overall, appearance, aroma, and texture for SD cultivar[1)]

Sample	Overall	Appearance	Aroma	Texture
Frozen cooked rice	5.94±1.61[a]	5.98±1.53[a]	6.16±1.35[a]	5.98±1.62[a]
Home-made cooked rice	5.98±1.20[a]	5.82±1.45[a]	6.10±1.04[a]	5.76±1.53[ab]
Aseptic-packaged cooked rice	5.28±1.34[b]	5.84±1.38[a]	5.20±1.26[b]	5.24±1.51[b]
p-value	0.007	0.773	0.000	0.039

[1)]Means with the same letter within the column are not significantly different at p=0.05 by Duncan's post-hoc analysis.

pared to the results of the IM (Table 2).

Mean consumer acceptance ratings for SD are shown in Table 6. SD cultivars showed significant differences in overall acceptance in relation to ACR ($p<0.007$), hence the reason that SD is used in commercial FCR rather than in commercial ACR. The acceptance of aroma ($p<0.001$) and texture ($p=0.040$) were significantly lower for ACR as compared to FCR and HCR. No statistical difference existed in the acceptance of appearance between FCR, HCR, and ACR ($p>0.05$). The consumer segmentation of the three samples of SD by AHC was different from that with the IM (Table 7). Cluster 1 is the consumer group that did not like cooked rice. For this group only HCR obtained a rating of slightly liked. Consumers in cluster 2 liked the cooked rice sample, FCR, and HCR. Consumers in cluster 3 liked FCR and ACR, but did not like HCR. These segmentation groups can be the supporting evidence in the large ranges of standard deviation in consumer acceptance ratings. Seventy four percent of consumers who evaluated SD cultivar liked FCR while about 60% of consumers liked FCR of IM cultivar, showing why commercial frozen cooked rice producers have used this cultivar for their products. Sensory characteristics between the FCR and HCR were statistically different, but the consumer acceptance ratings for FCR and HCR were similar to that of the IM cultivar. Different patterns in consumer acceptance of the three types of cooked rice by AHC can justify the differences in sensory characteristics between FCR and HCR, although the mean ratings for consumer

Table 7. Agglomerative hierarchical clustering analysis (AHC) from the results of consumer acceptance tests for SD cultivar by 50 consumers[1)]

Cluster	Subject	FCR	HCR	ACR
1	13	3.69±0.75	5.62±1.12	4.69±1.36
2	25	7.04±0.89	6.80±0.71	5.20±1.22
3	12	6.08±0.67	4.67±0.65	6.08±1.24

[1)]FCR, HCR, and ACR means frozen cooked rice, home-made cooked rice, and aseptic-packaged cooked rice, respectively.

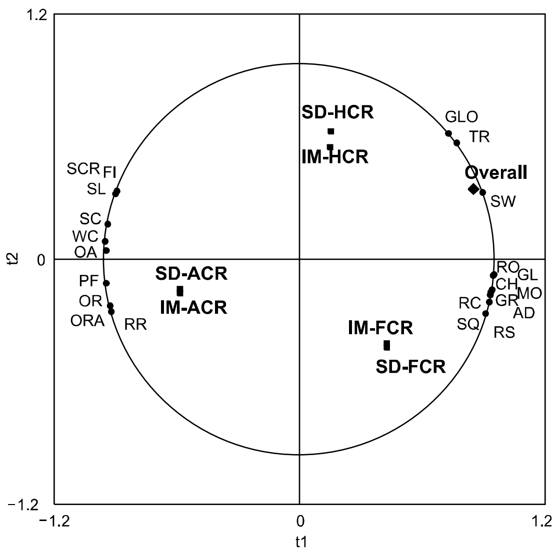

Fig. 1. Correlation map of 22 descriptive attributes, 6 cooked rice samples, and a mean overall acceptance rating by Partial Least Square regression (PLSR) analysis. A diamond means a mean overall acceptance. Squares mean cooked rice samples. Circles mean descriptive attributes. FCR, HCR, and ACR mean frozen-cooked rice, home-cooked rice, and aseptic-packaged cooked rice, respectively. ORA, old rice aroma; OA, off-aroma; SW, sweet; RO, roasted; GR, glutinous rice; RC, rice cake; RR, raw rice; RS, rice starch; OR, old rice; FI, firmness; GL, glutinousness; MO, moistness; CH, chunkiness; AD, adhesiveness; SC, scatteredness; SQ, squishiness; PF, particle feeling; GLO, glossiness; TR, transparency; SL, slickness; SCR, size of cooked rice; and WC, white color.

acceptance for FCR and HCR were similar.

By correlating the mean overall acceptance ratings of six samples and the descriptive analysis results, we can find out which attributes of the rice were positive or negative, and which were keys in determining overall acceptance. The attributes were analyzed by partial least square regression (PLSR) (Fig. 1) and showed that sweet, transparency, glossiness, roasted, glutinousness, chunkiness, moistness, glutinous rice, adhesiveness, rice shape, rice starch, and squashiness were positively related to the overall acceptance of the cooked rice samples, while raw rice, old rice, old rice aroma, a particle feeling, off-aroma, white color, scatteredness, slickness, size of cooked rice, and firmness were negatively related to the overall acceptance. When looking at the correlation between samples and attributes, FCR was closely related to roasted, glutinousness, chunkiness, moistness, glutinous rice, adhesiveness, rice shape, rice starch, and squashiness. HCR was strongly related to transparency and glossiness. ACR was strongly related to raw rice, old rice, old rice aroma, particle feeling, off-aroma, white color, and scatteredness. The values of Variable Importance of the Projection (VIP) for components 1 and 2 are presented in Fig. 2. The attributes that had a high VIP value (>1.0) can be considered as key attrib-

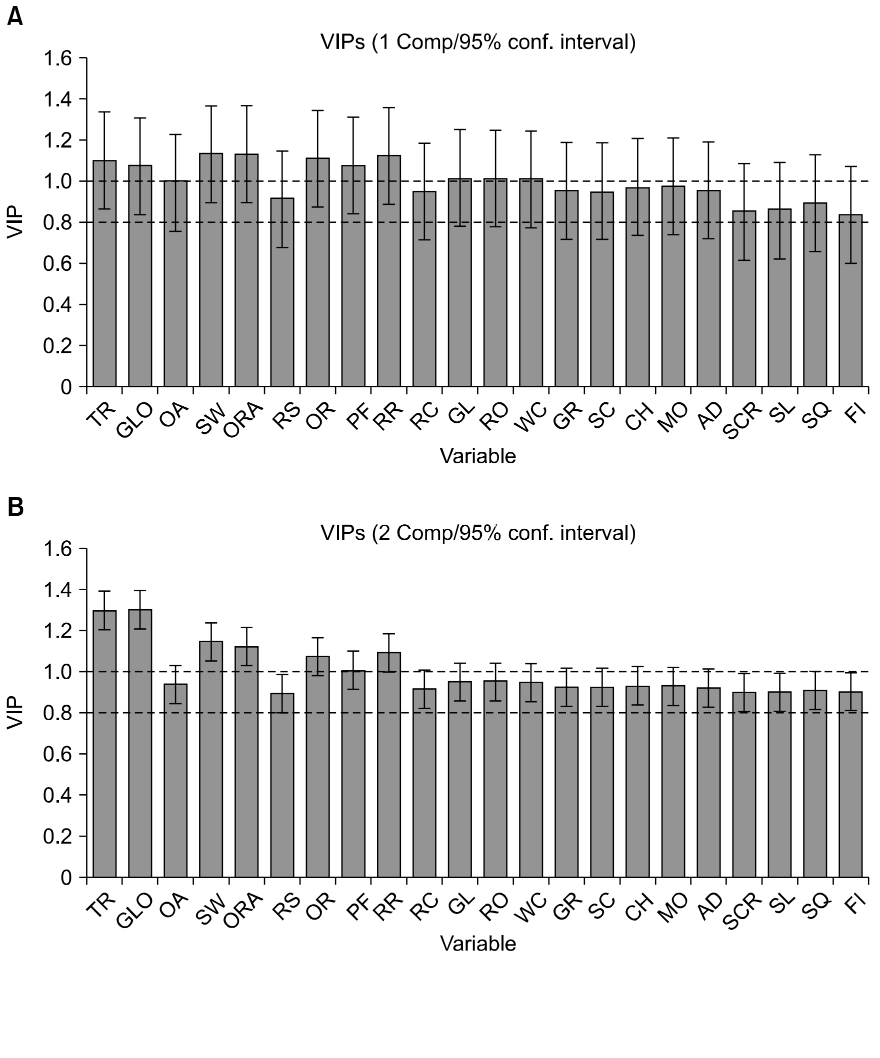

Fig. 2. Variable Importance in the Projection (VIP) of each attribute for components 1 and 2 of 6 cooked rice samples. ORA, old rice aroma; OA, off-aroma; SW, sweet; RO, roasted; GR, glutinous rice; RC, rice cake; RR, raw rice; RS, rice starch; OR, old rice; FI, firmness; GL, glutinousness; MO, moistness; CH, chunkiness; AD, adhesiveness; SC, scatteredness; SQ, squishiness; PF, particle feeling; GLO, glossiness; TR, transparency; SL, slickness; SCR, size of cooked rice; and WC, white color.

utes that influence the overall acceptance. Transparency, glossiness, sweet, glutinousness, and roasted influenced the overall acceptance positively. Old rice aroma, old rice, particle feeling, raw rice, and white color influenced the overall acceptance negatively. Since cooked rice is a bland sample, there was no dominant attribute that influenced the overall acceptance. Throughout the PLSR, we can infer that the cooked rice that is highly accepted from the consumers should have an initial appearance of transparency and glossiness. Once the consumers have chewed the cooked rice sufficiently glutinousness should be perceived together with a sweet taste and a roasted flavor. In addition, no perception of an old rice flavor should be experienced, as this is considered a negative characteristic, while raw rice and a feeling of particles are likely to communicate the characteristics of undercooked rice to the consumers.

CONCLUSION

The rapid freezing process for the processing of cooked rice is an effective processing method for maintaining the quality of cooked rice as compared to HCR, and offers a better quality of cooked rice than ACR. About 50% of consumers in both consumer tests liked both FCR and HCR. Through this study, it was verified that there are variations in the acceptance levels for FCR, HCR, and ACR. For example, consumers who liked HCR did not necessarily like FCR, and vice versa. Although FCR was acceptable to the entire consumer population, more than 60% of consumers were satisfied with the IM cultivar and 74% with the SD cultivar, a good indication for those in the business of frozen cooked rice products. The FCR market will be getting larger as more people live alone and have no time to cook. Developing various FCR products would attract these people by offering a similar quality of cooked rice compared to the rice cooked traditionally at home.

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