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Using Check-All-That-Apply (CATA) method for determining product temperature-dependent sensory-attribute variations: A case study of cooked rice☆

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ABSTRACT

Temperatures of most hot or cold meal items change over the period of consumption, possibly influencing sensory perception of those items. Unlike temporal variations in sensory attributes, product temperature-induced variations have not received much attention. Using a Check-All-That-Apply (CATA) method, this study aimed to characterize variations in sensory attributes over a wide range of temperatures at which hot or cold foods and beverages may be consumed. Cooked milled rice, typically consumed at temperatures between 70 and 30 °C in many rice-eating countries, was used as a target sample in this study. Two brands of long-grain milled rice were cooked and randomly presented at 70, 60, 50, 40, and 30 °C. Thirty-five CATA terms for cooked milled rice were generated. Eighty-eight untrained panelists were asked to quickly select all the CATA terms that they considered appropriate to characterize sensory attributes of cooked rice samples presented at each temperature. Proportions of selection by panelists for 13 attributes significantly differed among the five temperature conditions. "Product temperature-dependent sensory-attribute variations" differed with two brands of milled rice grains. Such variations in sensory attributes, resulted from both product temperature and rice brand, were more pronounced among panelists who more frequently consumed rice. In conclusion, the CATA method can be useful for characterizing "product temperature-dependent sensory attribute variations" in cooked milled-rice samples. Further study is needed to examine whether the CATA method is also effective in capturing "product temperature-dependent sensory-attribute variations" in other hot or cold foods and beverages.

1. Introduction

Consumer acceptance of foods or beverages often varies with their serving temperatures (Brown & Diller, 2008; Cardello & Maller, 1982; Lee & O'Mahony, 2002). In general, consumers' hedonic ratings for certain foods or beverages are the highest in the temperature ranges in which they are usually consumed (Cardello & Maller, 1982). Serving temperatures have been also found to influence taste intensities. More specifically, psychophysical studies have demonstrated that taste intensities of basic taste solutions change with serving temperatures (Bartoshuk, Rennert, Rodin, & Stevens, 1982; Lipscomb, Rieck, & Dawson, 2016; Moskowitz, 1973; Pangborn, Chrisp, & Bertolero, 1970), while those results have been inconsistent. Moreover, the effect of serving temperatures on taste intensities has been observed in food or beverage products (Drake, Yates, & Gerard, 2005; Kim, Samant, Seo, & Seo, 2015; Ross & Weller, 2008; Yau & Huang, 1996).

People generally have their meals over a period of 10 to 60 min (Bell & Pliner, 2003). In other words, when people consume hot or cold meal-products, people may experience their meals over a wide range of product temperatures since those temperatures change over time. Such temperature variations of hot or cold foods and beverages can be more pronounced when those are consumed concurrently with other activities, such as performing office work or engaging in social conversations. These observations suggest that sensory professionals should consider potential variations in sensory attributes of hot or cold foods and beverages over a wider range of product temperatures that consumers typically encounter in daily life (Seo, Lee, Jung, & Hwang, 2009). However, in most sensory studies of hot or cold food/beverage products, the products have been evaluated at specific serving temperatures, but not at a range of product temperatures in which those are usually consumed.

Serving temperatures have been found to affect intensities of sensory attributes in food or beverage products. In most sensory studies regarding the effect of serving temperatures, food or beverage samples

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have been compared with respect to attribute intensities between two (Francis et al., 2005; Yau & Huang, 1996) or among three serving-temperature conditions (Cliff & King, 2009; Drake et al., 2005; Kähkönen, Tuorila, & Hyvönen, 1995; Ross & Weller, 2008). However, there has only been a limited number of studies that focused on such temperature-dependent changes in sensory attributes over a wider range of product temperatures, i.e., among four or more serving-temperatures. For example, Kim et al. (2015) instructed both 8 trained and 62 consumer panelists to evaluate saltiness intensities of salt water, chicken broth, and miso soup at 5 different serving temperatures: 80, 70, 60, 50, and 40 °C. In another study by Stokes, O'Sullivan, and Kerry (2016), 10 panelists were asked to rate intensities of 14 sensory attributes of brewed coffee presented at 7 different serving temperatures: 77, 75, 70, 60, 50, 40, and 30 °C. In a recent study conducted by Steen, Waehrens, Petersen, Münchow, and Bredie (2017), 8 panelists were asked to rate intensities of 8 sensory attributes for brewed coffee served at 6 different serving temperatures: 62, 56, 50, 44, 37, and 31 °C. Intensities of four sensory attributes, i.e., overall intensity, sweet note, bitter note, and roasted flavor, were found to differ as a function of serving temperature. In particular, brewed coffee samples evaluated at 50 °C or higher temperatures were more associated with "overall intensity", "bitter note", and "roasted flavor" attributes, while those evaluated at 44 °C or lower temperatures were more associated with "sour note", "sweet note", and "tobacco flavor" attributes.

Since the temperatures of hot food or beverage products quickly change over time, the number of sensory attributes evaluated at specific serving temperatures has been limited in the aforementioned studies. Due to the limited number of sensory attributes used in the scoring-based traditional methods, a "rapid sensory profiling technique" seems to be more suitable for capturing dynamics of temperature-dependent sensory attributes in hot or cold foods and beverages. Using one of the rapid sensory profiling techniques, i.e., the projective mapping (Napping) method (Pagès, 2005), Ross, Weller, and Alldredge (2012) demonstrated serving temperature-dependent variations in sensory attributes of red wine products. More specifically, 12 trained panelists were asked to evaluate and sort six wine samples simultaneously presented at each three serving-temperatures: 10, 16, and 22 °C, based on sensory similarities. Subsequently, panelists were asked to characterize their sorted clusters of wine samples using sensory attribute terms. Such testing was replicated at each serving-temperature and the formation of clusters was compared between the two replications. Wine samples evaluated at lower temperatures (10 and 16 °C) showed greater variations between the replications with respect to the sorted clusters of wine samples than did those evaluated at higher temperature (22 °C). In addition, clusters of wine samples served at 22 °C were characterized more frequently as having "leather" and "low astringent" attributes, while those served at 10 or 16 °C were described more frequently as having "bitter", "smooth", and "high astringent" attributes.

The Napping method, however, seems inapplicable to sensory studies aiming at characterizing variations in sensory attributes of hot food or beverage products due to following reasons. First, panelists may have a difficulty in simultaneously evaluating hot food or beverage samples served at different temperatures, especially when there are many samples to be evaluated. Second, it seems difficult to control the temperature of the tongue during a Napping task of hot food or beverage samples, simultaneously presented, at different temperatures. The temperature of the tongue has been found to play an important role in modulating the associations between sample temperature and sensory perception (Green & Frankmann, 1987; Mony et al., 2013).

Using another rapid sensory profiling technique, i.e., Check-All-That-Apply (CATA) questions (Adams, Williams, Lancaster, & Foley, 2007), this study aimed to characterize variations in sensory attributes with changing temperatures of hot or cold food/beverage products. CATA questions consist of a list of sensory attributes (in the form of words or phrases) from which trained or untrained panelists can select all the attributes that they consider appropriate to characterize each sample (Valentin, Chollet, Lelièvre, & Abdi, 2012). Even though CATA questions yield only binary outcomes (checked or unchecked data), the use of CATA questions on naïve consumer panelists has been found not only to demonstrate high discriminative capability among test samples, but also to produce results similar to those obtained from descriptive sensory analysis (Ares, Barreiro, Deliza, Giménez, & Gámbaro, 2010; Bruzzone, Ares, & Giménez, 2012; Cadena et al., 2014). Moreover, CATA questions have been considered consumer-friendly, easy to understand, and highly reproducible, making this methodology applicable to a large number of consumer panelists (Jaeger et al., 2013). Building on these methodological merits of the CATA questions, the CATA method permits panelists to quickly select all the attributes they consider appropriate to characterize each sample over a temperature range in which the test products can be consumed (e.g., for cooked rice, 70 to 30 °C). In this way, results from the CATA method may draw a "big picture" view as to how sensory attributes can change with temperatures of hot or cold foods and beverages.

Cooked rice serves as a particularly apt example for illustrating variations in temperature-dependent sensory attributes during eating. In many Asian countries, cooked rice presented at hot temperatures (e.g., 70 °C) is consumed while its temperature decreases over the period of eating. Moreover, cooked rice is often consumed at near or even below room temperature (20 °C) in some countries. Nevertheless, there is limited information on the potential influence of temperature changes on sensory attributes of cooked rice during eating. In addition, since sensory perception of certain foods or beverages is modulated by dietary habit and familiarity (Kim et al., 2015; Ludy & Mattes, 2012), it is worth examining as to whether the effect of temperature changes on sensory attributes of cooked rice varies with dietary habit and familiarity, particularly the frequency of rice consumption. Therefore, the primary objectives of this study are to characterize "product temperature-dependent sensory-attribute variations" of cooked rice using the CATA method, and to determine whether such attribute-variations can be affected by frequency of rice consumption.

2. Materials and methods

This study was conducted according to the Declaration of Helsinki for studies on human subjects. The protocol used in this study was approved by the Institutional Review Board of the University of Arkansas (Fayetteville, AR, USA). A written informed consent was obtained from each participant prior to participation.

2.1. Panelists

Eighty eight rice-consumers (65 females, 23 males) ranging in age from 18 to 75 [mean ± standard deviation (SD) = 37 ± 14] were recruited through the consumer profile database of the University of Arkansas Sensory Service Center (Fayetteville, AR, USA). That database contains profiles of > 6200 Northwest Arkansas residents. More than half the panelists were Caucasians (N = 46), followed by 35 Asians, 6 Latino-Americans, and 1 Native American. Each panelist self-reported having no clinical history of major diseases such as cardiovascular disease, diabetes, cancer, or renal diseases. In addition, all panelists reported that they had purchased rice-grain products for their consumption sometime during the three months prior to study participation. Finally, panelists were asked to answer on 7 category scales how frequently they eat rice grain-based products: 1 = never, 2 = < 1 per month, 3 = 2–3 times per month, 4 = 1–2 times per week, 5 = 3–4 times per week, 6 = 5–6 times per week, and 7 = every day. Based on their frequency of rice consumption, panelists were classified into two groups: 1) "frequent consumption group" (≥ 3 times per week; N = 65) and 2) "non-frequent consumption group" (≤ 2 times per week; N = 23).

2.2. Samples and preparation

Two different brands of milled long-grain rice, "brand G" and "brand M", were purchased from a local supermarket (Fayetteville, AR, USA). The cultivars of the commercial rice-grain products were unknown. Each milled rice-grain product (300 g) was cooked in an electronic rice cooker (RC3314W, Black & Decker, Beachwood, OH, USA) for 25 min using a 1:1.8 (w/w) rice-to-water ratio. Cooked rice was held in the rice cooker for 5 min and then gently fluffed and mixed. Next, 45 g of the cooked rice was placed in a 118-mL Styrofoam cup and covered with a plastic lid (Dart Container Co., Mason, MI, USA). The temperature of each cooked rice sample contained in the cup was traced using a thermometer (Taylor, Oak Brook, IL, USA) placed through a small hole in the lid until it reached one of the target temperatures: 70, 60, 50, 40, and 30 °C. An additional test, using 34 untrained panelists (22 females and 12 males) ranging in age from 21 to 76 [mean ± standard deviation (SD) = 42 ± 18], showed that panelists could evaluate each cooked rice sample for 72.2 s (SD = 16.0) on average. In addition, over a period of sample evaluation (i.e., from start to end), temperatures of cooked rice samples decreased on average: 7.9 °C (SD = 3.6) for 70 °C; 5.5 °C (SD = 3.0) for 60 °C; 4.4 °C (SD = 2.2) for 50 °C; 2.5 °C (SD = 1.4) for 40 °C; and 2.0 °C (SD = 1.0) for 30 °C. As soon as the temperature was within ± 2 °C of the target temperature, cooked rice samples were promptly presented to panelists.

2.3. Check-All-That-Apply (CATA) question

Terms used in the CATA question to be evaluated in this study were collected from previous research that performed descriptive sensory analyses of cooked rice (Bett-Garber, Champagne, Ingram, & McClung, 2007; Billiris, Siebenmorgen, Meullenet, & Mauromoustakos, 2012; Limpawattana & Shewfelt, 2010; Prakash et al., 2005; Rodríguez-Arzuaga, Cho, Billiris, Siebenmorgen, & Seo, 2016; Yau & Huang, 1996). In addition, to help develop the CATA question, 10 professionally trained panelists, at the University of Arkansas Sensory Service Center (Fayetteville, AR, USA), were asked to describe sensory attributes of cooked rice samples ("brand G" and "brand M") presented at temperatures ranging from 70 to 30 °C.

Based on both 1) previous research and 2) discussion with trained panelists and authors, the CATA question, included 35 terms (4 for appearance, 10 for aroma, 15 for taste/flavor, and 6 for texture), was determined (Fig. 1). In each sensory modality (each column in Fig. 1), the terms were presented in alphabetical order to assist panelists in quickly finding all attributes that they wanted to check. Lee, Findlay, and Meullenet (2013) showed that consumer panelists took significantly less time to answer CATA questions when the terms were listed in a fixed order than in the Williams design presentation order. In addition, the influence of CATA term order was previously found to be minimal with respect to consumer responses (Lee et al., 2013; also see Ares & Jaeger, 2013).

2.4. Procedure

Prior to a sample presentation, an introduction describing both the experimental protocol and the CATA question was verbally given to each panelist. In addition, all panelists were asked to review the terms listed on CATA question to ensure that they could understand all terms and become familiar with the CATA question prior to the actual test.

Following the orientation session, all panelists were asked to evaluate a total of 10 cooked milled-rice samples (2 brands × 5 serving temperatures) in a sequential monadic fashion. Half of the panelists tested "brand G" first while the other half did "brand M" first. Since this study aimed to determine sample temperature-dependent variations in sensory attributes of each cooked-rice sample, all 10 samples (i.e., 2 brands × 5 serving temperatures) were not randomly presented. The presentation order of the five serving-temperatures for each brand was randomized to minimize the potential influence of presentation order on both sensory perception and consumer responses (CATA task).

Cooked rice (45 g), placed in a Styrofoam cup identified with a three-digit code, was presented at one of the five serving temperatures. To minimize variations in sample temperature, panelists were asked to uncover the lid from the cup and evaluate the sample immediately after receiving it. Panelists were asked to quickly select all the attributes shown on the CATA list that they considered appropriate for characterizing sensory attributes of the cooked rice samples served. Panelists were asked to evaluate cooked rice samples in the order: aroma, appearance, taste/flavor, and textural attributes. Panelists were asked to evaluate aroma- and appearance-related attributes of cooked rice samples immediately after uncovering the lid from the cup. Panelists were then asked to evaluate taste/flavor and textural attributes using a white plastic spoon. The time interval between sample presentations was approximately 5 min. During each break, spring water (Clear Mountain Spring Water, Taylor Distributing, Heber Springs, AR) for palate cleansing was presented at 25 °C.

2.5. Data analysis

Data were analyzed using XLSTAT statistical software (Addinsoft, New York, NY, U.S.A.). As Meyners, Castura, and Carr (2013) previously proposed for an overall test of CATA data, chi-square testing

APPEARANCE (by looking at)		AROMA (by sniffing)		TASTE/FLAVOR (by tasting)		TEXTURE (by tasting)	
Glossy grains	☐	Dairy	☐	Bitter taste	☐	Chewy	☐
Loose grains	☐	Earthy	☐	Dairy	☐	Firm	☐
Plumpness	☐	Floral	☐	Earthy	☐	Loose particles	☐
White	☐	Grainy	☐	Floral	☐	Moistness of grains	☐
		Hay-like	☐	Grainy	☐	Soft	☐
		Metallic	☐	Grassy	☐	Sticky	☐
		Nutty	☐	Hay-like	☐		
		Popcorn	☐	Metallic	☐		
		Rancid	☐	Nutty	☐		
		Sulfur	☐	Popcorn	☐		
				Rancid	☐		
				Salty taste	☐		
				Sour taste	☐		
				Sweet taste	☐		
				Wet cardboard	☐		

Fig. 1. A ballot of the Check-All-That-Apply (CATA) question for cooked milled-rice samples.

was used to determine whether the proportions selected by panelists for all terms of the CATA question differed with temperature condition among the cooked rice samples. Chi-square testing was also performed to determine whether the proportions of selection for all terms of the CATA question differed as a function of a frequency of rice consumption: frequent consumers (≥ 3 times per week) versus non-frequent consumers (≤ 2 times per week) of rice.

Cochran's Q test (Cochran, 1950) was performed to determine whether the proportions of selection by panelists for individual terms of the CATA question differed as a function of cooked-rice temperature, milled rice-grains brand, or frequency of rice consumption. If there was a significant difference among the variables, post hoc multiple pairwise comparisons were performed using McNemar's test with Bonferroni alpha adjustment. In addition, correspondence analysis, based on chi-square distance, was used to visualize associations between the CATA terms and the temperatures of cooked rice. Significant terms determined by Cochran's Q test were used for correspondence analysis. A statistically significant difference was defined to exist when $P < 0.05$.

3. Results

3.1. Overall effects of sample temperature changes on sensory attributes of cooked milled rice

To determine whether the proportions of selection by panelists for all terms of the CATA question differed as a function of sample temperature, the data were collapsed into the five temperature groups: 70, 60, 50, 40, and 30 °C. Specifically, 26.0, 25.3, 25.2, 25.0, and 24.8% of 35 CATA terms were selected at 70, 60, 50, 40, and 30 °C, respectively. Chi-square test revealed that the proportions of selection by panelists for all terms of the CATA question were not significantly different among the five temperatures evaluated in this study ($P = 0.59$). In other words, the frequencies of selected terms were not significantly affected by the cooked-rice temperature.

Table 1 is a contingency table showing the proportions of selection

Table 1
A contingency table of the proportions of selection by 88 panelists across all 10 cooked rice samples for individual terms of the Check-All-That-Apply (CATA) question.

Terms	Sample temperatures					P-value
	70 °C	60 °C	50 °C	40 °C	30 °C	
Appearance						
Glossy grains	0.27b	0.26b	0.29ab	0.40a	0.36ab	0.002
Loose grains	0.36b	0.43ab	0.48a	0.47ab	0.52a	0.002
Plumpness	0.57a	0.51ab	0.45ab	0.40b	0.43b	< 0.001
Aroma						
Grainy	0.58a	0.50a	0.55a	0.47a	0.46a	0.013
Rancid	0.09a	0.07a	0.08a	0.13a	0.14a	0.010
Taste/flavor						
Bitter taste	0.10b	0.15ab	0.15ab	0.23a	0.18ab	0.001
Hay-like	0.08b	0.18ab	0.14ab	0.18ab	0.18a	0.009
Nutty	0.23a	0.14a	0.19a	0.14a	0.16a	0.020
Sweet taste	0.31a	0.21ab	0.22ab	0.19b	0.21ab	0.004
Texture						
Firm	0.28c	0.40bc	0.36c	0.60a	0.51ab	< 0.001
Moistness of grains	0.43a	0.32ab	0.27b	0.20b	0.21b	< 0.001
Soft	0.48a	0.40a	0.43a	0.24b	0.24b	< 0.001
Sticky	0.39a	0.38a	0.31a	0.28a	0.30a	0.013

To determine overall effects of sample temperature changes on sensory attributes of cooked milled rice, the data from brand G and brand M were combined.
Cochran's Q test was performed to determine whether the proportions of selection by panelists for individual terms of the CATA question differed as a function of cooked-rice temperature. Only significant terms ($P < 0.05$) were shown.
Post hoc multiple pairwise comparisons were performed using McNemar's test with Bonferroni alpha adjustment. The proportions with different letters within each row represent a significant difference at $P < 0.05$.

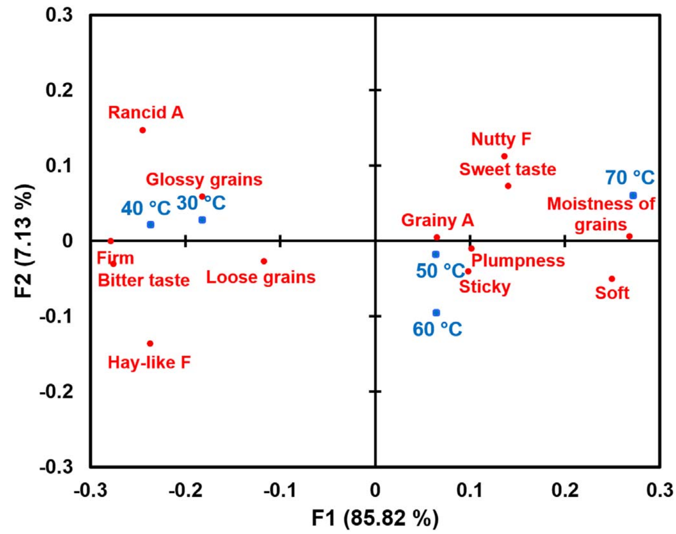

Fig. 2. A bi-plot drawn by the correspondence analysis, explaining 92.95% of total variance, in the association between sample temperatures and sensory attributes in cooked milled-rice samples. "A" and "F" next to sensory attribute term represents "aroma" and "flavor", respectively.

by panelists across all samples for individual terms listed on the CATA question. A higher proportion, i.e., closer to 1.00, means that, among the 10 samples the term was more frequently selected by panelists (2 brands at 5 temperatures). Cochran's Q test revealed that panelists perceived and identified 13 attributes of cooked rice samples differently as a function of sample temperature: 3 appearance attributes (glossy grains, loose grains, and plumpness), 2 aroma attributes (grainy and rancid), 4 taste/flavor attributes (bitter taste, hay-like, nutty, and sweet taste), and 4 textural attributes (firm, moistness of grains, soft, and sticky).

A bi-plot of correspondence analysis (Fig. 2), explaining 92.95% of total variance, illustrates obvious associations between sample temperatures and sensory attributes. More specifically, while cooked rice samples consumed at 70 °C were associated with "sweet taste", "nutty flavor", "moistness of grains", and "soft" attributes, those consumed at 40 °C or 30 °C were associated with "glossy grains", "loose grains", "rancid aroma", "bitter taste", "hay-like flavor", and "firm" attributes. Based on the CATA terms selected by panelists, cooked rice samples could be classified into three groups, i.e., 1) 70 °C, 2) 60 and 50 °C, and 3) 40 and 30 °C, mainly by the X-axis (F1) that explains 85.82% of the total variance. This result indicates that sensory attributes may be perceived differently depending on the temperatures at consumption.

3.2. Variations in temperature-dependent sensory attributes as a function of brand of milled rice grains

Temperature-dependent sensory attribute variations were examined for each brand of milled rice grains. For brand G, Cochran's Q test revealed that 9 attributes of cooked rice samples varied with sample temperatures: i.e., "plumpness" ($P < 0.001$), "bitter taste" ($P = 0.005$), "hay-like" ($P = 0.01$), "nutty flavor" ($P = 0.048$), and "sweet taste" ($P = 0.004$), "firm" ($P < 0.001$), "moistness of grains" ($P < 0.001$), "soft" ($P < 0.001$), and "sticky" ($P = 0.04$). A bi-plot of correspondence analysis [Fig. 3(A)], explaining 93.59% of total variance, demonstrates that the cooked rice samples consumed at 70, 60, and 50 °C were more associated with "plumpness", "nutty flavor", "sweet taste", "moistness of grains", "soft", and "sticky" attributes, while those consumed at 40 °C and 30 °C were more related to "bitter taste", "hay-like flavor", and "firm." For brand M, 6 attributes of cooked rice samples, such as "glossy grains" ($P < 0.001$), "loose grains" ($P = 0.006$), "bitter taste" ($P = 0.003$), "firm" ($P < 0.001$),

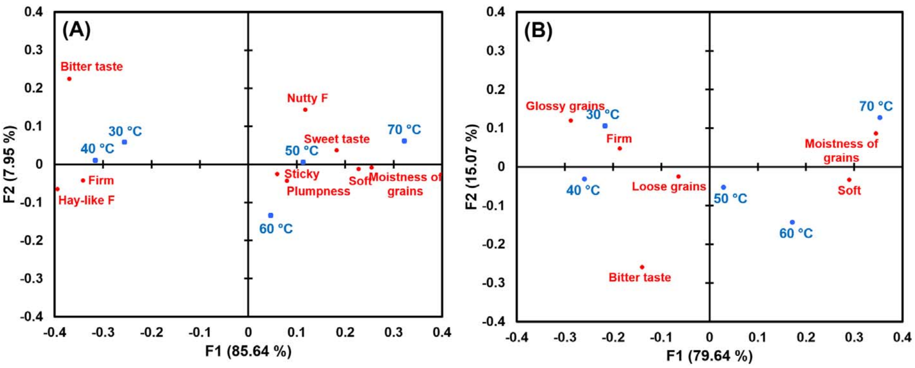

Fig. 3. Two bi-plots drawn by the correspondence analyses in the association between sample temperatures and sensory attributes in cooked milled-rice samples as a function of brand of milled rice grains: brand G (A) and brand M (B). "F" next to sensory attribute term represents "flavor".

"moistness of grains" ($P < 0.001$), and "soft" ($P = 0.002$), were found to vary with sample temperatures. Compared to brand G, brand M showed less variation as a function of sample temperature in terms of taste/flavor-related attributes. A bi-plot of correspondence analysis [Fig. 3(B)], explaining 94.71% of total variance, shows that while cooked rice samples consumed at 70 °C were more associated with "moistness of grains" and "soft" attributes, those consumed at 40 °C and 30 °C were related to "glossy grains" and "firm."

The proportions of selection by panelists for individual terms of the CATA were compared between the two brands at each sample-temperature (Table 2). Brand differences with respect to the proportion of selection for individual CATA terms were most pronounced when cooked rice samples were consumed and evaluated at 60 °C. More specifically, while brand G was more frequently characterized as having "glossy grains", "plumpness", "grainy flavor", and "firm" attributes, brand M was more frequently reported as having "sulfur aroma" and "bitter taste". In contrast, the two brands, G and M, did not significantly differ with respect to the proportion of selection for individual CATA terms, except for the "glossy grains" attribute, when consumed and evaluated at 70 °C. In addition, compared to its counterpart, brand M produced a more detectable attribute of "hay-like aroma" when consumed at 50 °C, while brand G was more frequently identified as having "grainy flavor" at 30 °C.

When the combined data of brand G and brand M were analyzed using correspondence analysis, as shown in Fig. 4, the first two dimensions of the bi-plot could differentiate 10 cooked milled rice samples (2 brands × 5 temperatures). More specifically, those samples were differentiated by not only the temperature of cooked rice sample

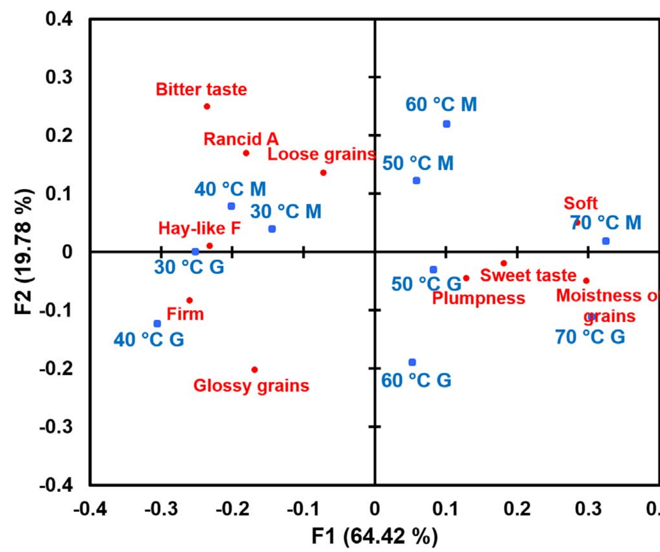

Fig. 4. A bi-plot drawn by the correspondence analysis in the association between sample temperatures and sensory attributes in 10 cooked milled-rice samples (2 brands × 5 sample temperatures). "G" and "M" represent "brand G" and "brand M" of milled rice grains. "A" and "F" next to sensory attribute term represents "aroma" and "flavor", respectively.

(F1 dimension explaining 64.42% of total variance), but also by the brand of milled rice grains (F2 dimension explaining 19.78% of total variance).

Table 2
Comparisons between the two brands of rice-grain products at each temperature of cooked rice samples with respect to the proportions of selection by 88 panelists for individual terms of the Check-All-That-Apply (CATA) question.

Temp.	Brand	Appearance			Aroma		Taste/flavor					Texture
		Glossy grains	Loose grains	Plump-ness	Hay-like	Sulfur	Bitter	Grainy	Hay-like	Sweet	Chewy	Firm
70 °C	Brand G	0.38										
	Brand M	0.16										
	P-value	0.001										
60 °C	Brand G	0.39		0.58		0.03	0.08	0.63				0.49
	Brand M	0.14		0.44		0.11	0.23	0.49				0.31
	P-value	< 0.001		0.03		0.008	0.003	0.02				0.009
50 °C	Brand G				0.14							
	Brand M				0.26							
	P-value				0.02							
40 °C	Brand G										0.56	0.66
	Brand M										0.67	0.55
	P-value										0.049	0.049
30 °C	Brand G							0.60				
	Brand M							0.46				
	P-value							0.02				

Cochran's Q test was performed to determine whether the proportions of selection by panelists for individual terms of the CATA question differed as a function of brand of milled rice grains: brand G versus brand M. Only significant terms ($P < 0.05$) were shown.

3.3. Variations in temperature-dependent sensory attributes as a function of the frequency of rice consumption

To determine whether the proportions of selection by panelists for all terms of the CATA question differed as a function of the frequency of rice consumption, the data were collapsed to two groups: frequent consumers (≥ 3 times per week) and non-frequent consumers (≤ 2 times per week) of rice. The proportions of selection by panelists for all terms of the CATA question were found to differ with a frequency of rice consumption. The proportion of selection (26.2%) by non-frequent consumers of rice for all CATA terms across 10 samples was significantly higher than the proportion of selection (24.9%) by frequent consumers of rice (≥ 3 times per week) ($P = 0.02$). However, such significant group-differences with respect to frequency of rice consumption were not observed when the proportion of selection was compared in terms of each sensory aspect: appearance ($P = 0.11$; frequent consumers of rice versus non-frequent consumers of rice = 49.7% vs. 52.7%), aroma ($P = 0.55$; 19.6% vs. 20.2%), taste/flavor ($P = 0.28$; 15.7% vs. 16.4%), and texture ($P = 0.10$; 40.5% vs. 43.1%).

Temperature-dependent variations in sensory attributes for cooked rice samples differed significantly with frequency of rice consumption. More specifically, more frequent consumers of rice showed temperature-dependent variations among 10 cooked rice samples with respect to 9 sensory attributes, such as "glossy grains" ($P = 0.01$), "loose grains" ($P = 0.01$), "plumpness" ($P = 0.004$), "bitter taste" ($P = 0.004$), "grainy flavor" ($P = 0.02$), "sweet taste" ($P = 0.004$), "firm" ($P < 0.001$), "moistness of grains" ($P < 0.001$), and "soft" ($P < 0.001$). As shown in Fig. 5(A), the bi-plot of the correspondence analysis could differentiate 10 cooked rice samples not only by sample temperature (F1; 70 °C vs. 60 and 50 °C vs. 40 and 30 °C), but also by sample brand (F2; brand M vs. brand G). While non-frequent consumers of rice also showed temperature-dependent variations among 10 cooked rice samples with respect to 6 sensory attributes, such as "glossy grains" ($P < 0.001$), "bitter taste" ($P = 0.007$), "nutty flavor" ($P = 0.02$), "firm" ($P = 0.002$), "moistness of grains" ($P = 0.009$), and "sticky" ($P = 0.01$), the bi-plot of the correspondence analysis, based on 6 such attributes, could differentiate 10 cooked rice samples neither by sample temperature, nor by sample brand [Fig. 5(B)].

4. Discussion

4.1. Value of characterizing variations in sensory attributes with temperature changes of hot or cold foods and beverages

Over the past decades, temporal variations with respect to sensory attributes during consumption of foods or beverages, from the first bite/sip to swallow, have been characterized using different methods of sensory evaluation, e.g., "Progressive Profiling" (Jack, Piggott, & Paterson, 1994), "Sequential Profiling" (Methven et al., 2010), "Time-Intensity analysis" (Larson-Powers & Pangborn, 1978), "Dual Attribute Time Intensity" (Duizer, Bloom, & Findlay, 1996), "Temporal Dominance of Sensations" (Pineau, Cordelle, & Schlich, 2003), and "Temporal Check-All-That-Apply" (Castura, Antúnez, Giménez, & Ares, 2016). However, there is limited information related to product temperature-related variations in sensory attributes of hot or cold foods and beverages. As aforementioned, the projective mapping (Napping) method has been used to determine variations with respect to a formation of product clustering as a function of product temperatures (Ross et al., 2012).

Using a rapid sensory profiling technique, the CATA method, this study aimed to characterize a profile of sensory attributes with increasing or decreasing temperatures of the samples to be evaluated, with consideration of the following three points. First, since people tend to eat their meals over an interval of 10 to 60 min (Bell & Pliner, 2003), temperatures of hot or cold foods and beverages change over the continuous period of meal consumption. For example, while people may taste hot miso soup at the beginning of consumption, they may experience lukewarm miso soup during or at the end of a meal. Second, preferred temperatures at which certain foods are typically consumed may differ among cultural backgrounds. For example, while cooked rice is typically consumed at 60 to 70 °C in Korea, it is more likely eaten at 25 to 30 °C in Ghana (Tomlins, Manful, Larwer, & Hammond, 2005). Furthermore, cooked rice in a lunchbox is most likely consumed at less than room temperature in Japan and Korea (Yau & Huang, 1996). Finally, temperatures of foods or beverages affect not only releases of volatile compounds (Francis et al., 2005; Steen et al., 2017), but may also affect sensory perception and acceptance (Brown & Diller, 2008; Cardello & Maller, 1982; Drake et al., 2005; Engelen et al., 2003; Kim et al., 2015; Lee & O'Mahony, 2002). These three points indicate that temperature variations of hot or cold foods and beverages often occur during consumption and further influence sensory perception of those items. Therefore, it is extremely valuable to successfully capture the dynamics in sensory attributes of hot or cold foods and beverages over a wide range of temperatures encountered by consumers across cultural backgrounds in daily life.

4.2. Check-All-That-Apply (CATA) method characterizing "product temperature-dependent sensory-attribute variations" in cooked milled rice

Even though previous studies using rating scales examined sensory attributes at different temperatures (Kim et al., 2015; Steen et al., 2017; Stokes et al., 2016), the number of attributes evaluated in those studies was limited because temperatures of hot food or beverage products change quickly over time. However, the CATA method could permit panelists to evaluate many attributes (e.g., 35 attributes in this study) with a minimum change of sample temperature. This method gave a "big picture" view of temperature-dependent variations in sensory attributes of cooked rice, at temperatures ranging from 70 °C to 30 °C. Based on the set of CATA terms selected by untrained panelists, cooked

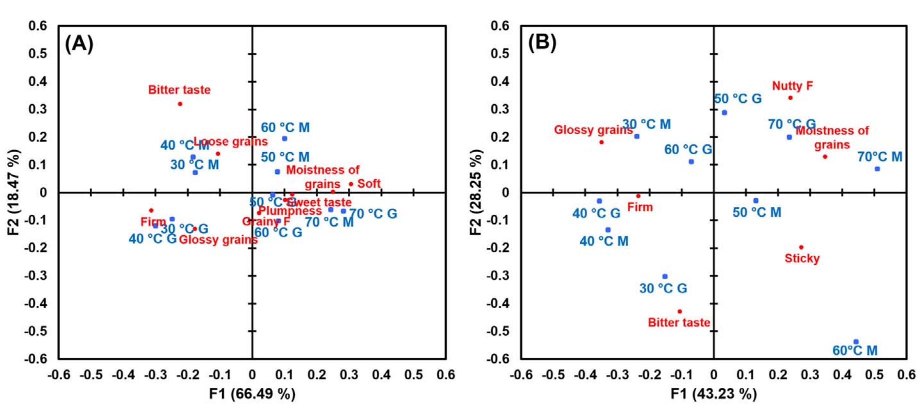

Fig. 5. A bi-plot drawn by the correspondence analysis in the association between sample temperatures and sensory attributes in 10 cooked milled-rice samples as a function of a frequency of rice consumption: frequent consumers of rice (A) and non-frequent consumers of rice (B). "G" and "M" represent "brand G" and "brand M" of milled rice grains. "F" next to sensory attribute term represents "flavor".

rice samples could be classified into three groups by F1 dimension (Fig. 2). In other words, sensory attributes of cooked milled-rice samples could be perceived differently in three temperature ranges: 1) 70 °C, 2) 60 to 50 °C, and 3) 40 to 30 °C. As shown in Table 1 and Fig. 2, 13 sensory attributes were found to be affected by the temperature of cooked milled rice. This result indicates that people may detect and identify different sensory attributes depending on the temperature of consumption or evaluation. Moreover, people may experience different sensory attributes during consumption since the temperature of hot cooked rice changes due not only to ambient temperature, but also because of food items or ingredients consumed along with cooked rice. Rice is popularly consumed with other dishes or as a carbohydrate source to be combined with other ingredients such as butter, oil, seasoning, dry seaweed, tomato sauce, or vegetables (Hatae et al., 1997), which may change temperature of cooked rice.

The present study demonstrated that cooked rice samples consumed at 70 °C were more frequently characterized as having "sweet taste", "nutty flavor", "moistness of grains", and "soft" attributes. In addition, cooked rice samples consumed at 40 °C or 30 °C were more associated with "glossy grains", "loose grains", "rancid aroma", "bitter taste", "hay-like flavor", and "firm" attributes. Sweetness perception at relatively low concentrations, as found in cooked rice, may increase with temperature (Bartoshuk et al., 1982), and enzymatic action of salivary α-amylase is enhanced with increasing temperature. These changes result in faster breakdown of cooked rice starch to glucose, explaining the most frequent detection of sweet taste at the highest serving temperature investigated (Engelen et al., 2003). This result was in agreement with previous research where sweetness rating of cooked rice was higher when evaluated at 60 °C rather than at 18 °C (Yau & Huang, 1996). In addition, while a desirable flavor attribute, "nutty flavor", was more often reported at higher temperatures, a "rancid flavor", regarded as an undesirable flavor attribute (Champagne, 2008), was more often characterized at lower temperatures (Fig. 2). This result emphasizes that sensory quality of cooked milled rice should be considered over a wide range of temperatures. For example, certain samples of cooked rice may produce undesirable aroma and flavor attributes at lower temperatures even though they might release highly desirable attributes at higher temperatures.

Notably, influences of temperature change on aroma attributes were not remarkable, possibly due to the fact that cooked milled rice is inherently subtle in aroma. Even though > 200 volatile compounds have been found in rice, only a few have been identified as contributing to aroma and flavor attributes of cooked rice (Champagne, 2008). Moreover, most olfactory-active volatile compounds that may affect aroma and flavor attributes have been observed in rice bran, i.e., in brown rice (Champagne, 2008; Jezussek, Juliano, & Schieberle, 2002). Therefore, temperature-dependent aroma and flavor attributes may differ with degree of milling, exhibiting detectable differences in cooked brown rice.

Finally, as expected, while cooked rice samples consumed at higher temperatures were more often characterized as having a "soft" attribute, those consumed at lower temperatures were associated with a "firm" attribute, possibly due to retrogradation of rice starch (Perdon, Siebenmorgen, Buescher, & Gbur, 1999). Degree of starch retrogradation has previously been found to correlate with firmness level of cooked milled rice (Perdon et al., 1999). Since the retrogradation process of rice starch is affected by structure and composition of starch, such as a content of amylose (Perdon et al., 1999), a ratio of amylose and amylopectin (Mariotti, Sinelli, Catenacci, Pagani, & Lucisano, 2009), and a ratio of chains with degree of polymerization > 10 in amylopectin (Lian, Kang, Sun, Liu, & Li, 2015), cooked rice samples varying in structure and composition of starch may show different patterns with respect to temperature-dependent textural attributes.

4.3. Product temperature-dependent sensory-attribute variations with the brand of rice-grains

Product temperature-dependent variations in sensory attributes were found to differ as a function of brand of milled rice grains. This result was in agreement with previous research that compared intensities of 13 sensory attributes in 4 cooked milled-rice samples at serving temperatures of both 60 °C and 18 °C (Yau & Huang, 1996). In the present study, temperature-dependent variations in sensory attributes, especially taste/flavor attributes, were more pronounced in brand G than in brand M. Moreover, unlike brand G, brand M showed temperature-dependent variations in glossy grains and loose grain attributes (Fig. 3). Such findings indicate that the CATA method can be useful for characterizing individual cultivars or brands of rice grain with respect to their profile of temperature-dependent sensory attributes. As shown in Fig. 4, cooked rice samples can be classified based on sensory attribute variations resulting not only from temperature of cooked rice, but also from the brand of rice grains.

In traditional methods of sensory evaluation, temperature changes in cooked rice samples during evaluation have not been considered (Jarma Arroyo & Seo, 2017; Meullenet, Marks, Griffin, & Daniels, 1999; Rodríguez-Arzuaga et al., 2016). However, as shown in Table 2, sample differences in sensory attributes varied with temperatures at which cooked rice was consumed and evaluated. While appearance attributes of two brands of rice products differed at 70 °C and 60 °C, the brand-induced differences in taste/flavor attributes were more pronounced at lower temperatures, i.e., at 60, 50, and 30 °C. In addition, brand differences in terms of textural attributes were present at 40 °C. Notably, brand differences with respect to sensory attributes were more frequently observed at 60 °C even though the proportions of selection by panelists for all CATA terms were not significantly different among the five temperatures of cooked rice. These outcomes showed that cooked rice samples of different brands can be perceived similarly or differently depending on the temperatures of consumption or evaluation. In addition, since only two brands of long grain rice were compared in this study, further research using a greater variety of rice cultivars and brands should be conducted to generalize the pattern of temperature-dependent sensory attributes of cooked rice. Furthermore, physicochemical analyses may help better understand temperature-dependent variations in sensory attributes of cooked rice samples.

4.4. Product temperature-dependent sensory-attribute variations with the frequency of rice consumption

This study showed that panelists who habitually consume cooked rice more frequently (≥ 3 times per week) were more sensitive to temperature-dependent sensory attributes compared to those who consume it less frequently (≤ 2 times per week). In other words, while frequent consumers of rice showed variations in the proportions of selection for CATA terms not only by sample temperature, but also by rice-grain brand, non-frequent consumers of rice did not show such results in their evaluation (Fig. 5). Interestingly, unlike frequent consumers of rice, non-frequent consumers of rice could not detect temperature-dependent aroma and flavor attributes in cooked rice samples, possibly due to low intensities of aroma and flavor attributes in cooked rice (Jarma Arroyo & Seo, 2017; Meullenet et al., 1999; Rodríguez-Arzuaga et al., 2016). In this way, weak aroma and flavor attributes of cooked milled-rice samples might be identified less accurately by non-frequent consumers of rice due to their lesser experiences with rice consumption.

Since frequent consumers of rice are more familiar with sensory attributes of cooked rice, they might have better ability to identify and differentiate attributes of cooked rice compared to non-frequent consumers of rice. Familiarity and frequency of consumption for certain food and beverage items have been found to affect sensory perception and liking of those items (Ayabe-Kanamura et al., 1998; Fjaeldstad, Sundbøll, Niklassen, & Ovesen, 2017; Kim et al., 2015; Seo et al., 2009). It was found that participants better identified or described odors that were more familiar to them (Ayabe-Kanamura et al., 1998; Fjaeldstad et al., 2017). Similarly, Ludy and Mattes (2012) showed that regular spicy food users outperformed non-users with respect to discriminability of burn level among spicy foods due to variation in red pepper content. Based on those studies, it was expected that the influence of temperature change on sensory attributes of cooked rice would be dependent on their familiarity with rice products, as well as their cultural background. Accordingly, people in Asian countries would be expected to show better performance in detecting temperature-dependent sensory attributes in cooked rice than people in the U.S., since > 90% of rice is consumed in Asian countries (Mohanty, 2013). Therefore, sensory results regarding product temperature-dependent variations in sensory attributes of cooked rice would be beneficial for breeders, processors, sensory professionals, marketers, and traders in the rice industry to construct a strategy for improvement of the eating quality of rice both in rice-eating countries and rice-importing countries. For example, rice grains that produce desirable attributes at lower temperatures could be more suitable for cooking rice for use in a lunch box, and these may be favorable to rice consumers in some Asian countries such as Japan or Korea.

5. Conclusions

To summarize, the results of this study using a Check-All-That-Apply (CATA) method showed that sensory attributes of cooked rice can vary with temperatures at which panelists eat or evaluate. In other words, consumers may perceive different sensory attributes with decreasing temperature of cooked rice during a period of rice consumption. Since product temperature-dependent sensory attributes differed by brand of rice grains, it is worth examining whether such variations can characterize specific cultivars or brands of rice grains. Moreover, temperature-dependent sensory-attribute variations were found to be more pronounced to panelists who more frequently consume cooked rice, meaning that consequences of temperature variation in cooked rice would become greater in rice-eating countries. In conclusion, the CATA method can be useful for characterizing variations in sensory attributes with temperatures of cooked rice samples. Further study is needed to determine whether the CATA method is effective in capturing "product temperature-dependent sensory-attribute variations" in other hot or cold foods and beverages.

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