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Article

Freshly Prepared or Reheated? The Effect of Cold Storage and Reheating of Parboiled Rice on Consumer Preference and Acceptability in Auckland, New Zealand

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Abstract:

Background: Previous in vitro and in vivo studies have demonstrated that storage of cooked rice at 4 °C for 24 h and reheating to 65 °C significantly reduced starch digestibility and postprandial glycaemic responses. Moreover, the effect was greater for parboiled rice compared to other rice varieties commonly consumed in New Zealand. This study aimed to evaluate consumer preferences of related sensory attributes and consumer acceptability of several rice varieties freshly cooked or reheated. **Method**: Sixty-four consumers volunteered and recorded on Visual Analoge Scales their preference and acceptability of freshly prepared or cold-stored and reheated medium grain white, medium grain brown and parboiled rice. **Results**: All six rice samples were accepted by participants (average 54%). Reheated parboiled rice and reheated medium grain brown rice were both accepted by participants as a preferred staple meal compared to other rice samples. Among all rice samples, the sweetness and the flavour of freshly cooked warm medium-grain white rice were less preferred (scored 42.1% and 45.0% respectively) compared with other samples ($P = 0.05$). Participants who prepared and consumed brown rice at home regularly (more than 10 times per month), preferred the reheated brown rice (73.8% (67.4, 80.2)) and reheated parboiled rice (74.3% (67.9, 80.7)) ($P < 0.001$). **Conclusions**: It is suggested that reheated parboiled rice, with the lowest starch digestibility and glycaemic impact (both in vitro glucose release and in vivo glucose response) could be accepted as a healthier alternative for the daily staple meal.

Keywords: parboiled rice; medium-grain white rice; medium-grain brown rice; sensory evaluation; consumer acceptability

1. Introduction

Rice is widely consumed staple food, however, there is wide variation in the rice products consumed. Previous experiments on *in vitro* rice starch digestion [1] and human participant's glycaemic responses to freshly cooked and reheated rice samples [2] demonstrated that rice parboiled, cooked and cold stored for 24-hours reduced and delayed the digestion of rice starch, extended the chewing time, decreased the postprandial glycaemic responses and had improved palatability compared to white and brown rice. This evidence would support advice that substituting parboiled rice for commonly consumed medium grain white rice products and adopting the cold

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storage preparation method may improve postprandial glycaemic response, reduce glycaemic load and benefit long-term glycaemic management among rice consumers.

Reported physico-chemical differences among cooked rice meals may be considered to be an important attribute to different sensory properties that may influence rice consumers' choice. Parboiled rice is steam treated paddy rice that has a pale yellow colour, a harder and firmer texture, and a stronger, unique flavour. In comparison, white rice has a softer, adhesive texture and creamy starchy flavour [3,4]. It has been suggested that these unique characteristics of parboiled rice are disliked by rice consumers, especially those from East and Southeast Asian backgrounds [5,6], but favoured by consumers in India, Pakistan, Brazil and Ghana [3,6,7]. Moreover, various post-cooking methods (including cooling, cold storage, and reheating) may also influence the physical properties and sensory attributes of cooked rice [8].

Recent studies have suggested that changing demographic factors, including cultural diversity and infiltration, age distribution, lifestyle and the shift towards more convenience in food preparation and disposable income, might affect consumer liking and demand for food [9,10]. In an ethnically diverse population such as Auckland, New Zealand, these factors present challenges when introducing a healthier dietary recommendation as the sensory acceptability to consumers may differ. Therefore, a study of Auckland rice consumers was proposed in order to understand better the diverse consumer preferences of rice prepared in different ways. As consumers evaluate food quality predominantly based on both the sensory and nutritional characteristics [11], a blinded sensory acceptability test would assist with the recommendations of a healthier option of cooked rice as a staple food.

The purpose of this study was to evaluate whether reheated parboiled rice with a slower-glycaemic-release could be accepted and liked as a healthier alternative by Auckland consumers who commonly consume either plain cooked medium-grain white or brown rice as their staple grain. The study aimed to investigate the following questions: (1) Would consumers report that reheated parboiled rice has significant different sensory attributes (colour, texture, flavour and sweetness) compared with the other five rice samples (freshly cooked or reheated medium-grain white rice and medium-grain brown rice, and freshly cooked parboiled rice)? (2) Would reheated parboiled rice be acceptable to consumers?

2. Materials and Methods

2.1 Rice products

Three rice products were selected for the study and some characteristics are as follows:

- Australian imported raw medium grain white rice (SunRice®, Australia), which is widely available in Auckland, New Zealand. It was selected as the most commonly consumed staple rice and the control sample.
- Australian imported raw medium grain brown rice (SunRice®, Australia), which is widely available in Auckland, New Zealand. It was selected as a healthier alternative to medium grain white rice.
- Parboiled rice produced and imported from Thailand (RealRice®, Thailand imported). It is selected as the healthiest alternative based on the results from previous *in vitro* study on rice starch digestibility and glucose release [1].

The medium-grain white and medium-grain brown rice were characterised as medium-grain commercial rice (Oryza sativa L.) [12], and cultivated and processed in Riverina, Australia, in 2013. The parboiled long-grain rice was cultivated and - parboiled in Thailand and harvested and processed in late 2012 and 2013.

2.2 Cooking method

Cooking and storing-reheating methods were as for the previous studies [1,2]. The quantities of rice, water added and times of cooking were as recommended by the manufacturer. The temperature of cooking (100ºC) and reheating (65ºC) were monitored; and, the room temperature (23ºC) and

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humidity (35%) of the cooking environment remained stable. Three rice products were cooked in three separate domestic automated commercial rice cookers (Abode® Rice Cooker, BIGW_7963940) following the instructions provided by rice product manufacturers. To achieve full gelatinization (i.e., till automatic completion in the rice cooker), rice to water ratio were different for each rice product: 1 measuring cup of rice (141.9 g ± 5.0 g) to 1½ cups of water (375 mL) for medium grain white rice were cooked for approximately 20 minutes; 1 cup of rice (130.8 ± 5.0 g) to 2 cups of water (500 mL) for medium grain brown rice were cooked for approximately 25 minutes; and, 1 cup of rice (135.3 g ± 5.0 g) to 2⅓ cups of water (583.3 mL) for parboiled rice were cooked for approximately 30 minutes. All freshly cooked rice was maintained in a sealed warm container at 65 ºC until served.

2.3 Storing and reheating method

Approximately 250 g of freshly cooked rice samples were weighed using electronic scales (Sartorius®, CP4202S) and spread evenly in a shallow plastic pan (4 cm deep, pre-cooled to 4 ºC in the refrigerator) and sealed with food wrap to prevent moisture loss and for food safety purposes. The sealed rice pans were placed in the refrigerator for rapid cooling to 4 ºC and for 24-hour storage. After 24 hours, the temperature of the rice was checked again and then the rice samples were reheated in the microwave (Sharp®, R99) at 1,000 W power, mixed thoroughly and the temperature checked several times until they were over 65 ºC. All reheated rice products were kept at 65 ºC until served.

2.4 Participants

Volunteer consumers were recruited at Auckland North Shore Akoranga area (including Auckland University of Technology (AUT) North Campus and surrounding area) and Auckland City (including AUT City Campus and surrounding area). Volunteers were screened by questionnaire to confirm they met the inclusion criteria of general good health; were 18 to 80 years old; were regular rice consumers (consuming plain cooked rice at least once per week for the previous year and intending to consume rice as staple food in the future); and had consented to complete the entire tasting and rating session (three freshly cooked and three reheated rice samples). Exclusion criteria included health issues (e.g. diabetes, cardiovascular diseases, cancer, and/or major surgery), known allergies, and difficulties in perceiving smell, taste or swallowing of foods. All participants were asked to fast for at least two hours before participating in the study. A sample size of over 60 was required to detect a difference of 14.8% between rice treatments based on F-test (ANOVA repeated measures) with an alpha value of 0.05, and beta value of 0.10 [13].

This study was approved by the AUT Ethics Committee (AUTEC) (Reference: 13/183 Which rice and why?).

2.5 Consumer questionnaire

Volunteers were interviewed during screening at two locations in Auckland (AUT North Campus and surrounding area in Akoranga Northshore; AUT City Campus and surrounding area at Auckland city centre) using central location testing. Participants (n=91) completed questionnaires to record demographics (age, gender, and ethnicity) and rice consumption habits (rice type, rice product, cooking method, frequency and the amount of rice consumed).

2.6 Sensory evaluation: consumer affective testing and acceptability

All participants (n=91) who completed questionnaires were asked to attend the tasting session. Twenty-seven participants dropped out because of not fasting (n=7) and unavailability (n=20). Consumer affective testing was conducted at AUT North Campus, Auckland, New Zealand between the hours of 10:00 am and 11:00 am. The six rice portions were prepared and subjected to affective testing in accordance to Lawless and Heymann [9] using Visual Analogue Scales (VAS). Each rice portion (50g) was assigned a 3-digit random code and presented unbranded under a clear food wrap cover. The six samples were assessed at the same time in individual booths under white light at room temperature (23±2 ºC) and humidity (35±3%). Six samples of rice were prepared: freshly cooked

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medium grain white rice, freshly cooked medium grain brown rice, freshly cooked parboiled rice, reheated medium grain white rice, reheated medium grain brown rice, and reheated parboiled rice. Each participant (n=64) tasted the six samples in a blind condition and evaluated the liking of each rice sample in relation to the sensory attributes (colour, taste, flavour, texture, and overall acceptability) on five 100mm unstructured line VAS (Figure 1). All participants were then asked report the acceptability of the rice sample as a replacement to their commonly consumed rice meal.

Figure 1 Visualised Analogue Scale (VAS) for measuring consumer liking in relation to sensory attributes (colour, taste, texture, and overall acceptability) on a 100mm unstructured line

To reduce the first order and carryover effects, the order of sample presentation was balanced using Williams Latin Square design [14]. Each participant was required to break for 2 minutes between each sample and cleanse their palate by rinsing mouth with filtered room temperature water between tastings.

2.5 Statistical analysis

Liking attributes were compared using two-way repeated measure analysis of variance (ANOVA) (post-hoc Tukey honestly significant differences (HSD) testing) with the six rice samples as a fixed factor and participants as a random factor to determine attributes that were discriminatory ($P < 0.05$) between rice samples using SPSS 12.0.1 (SPSS Inc., Chicago, USA). The attribute VAS scores were analysed with principal component analysis (PCA) with Varimax rotation using SigmaPlot (version 13.0.0, Systat Software Inc., US). The PCA plots were generated using XLSTAT (version 19.03, Addinsoft, US). One-way ANOVA was carried out on PCA scores to determine the significant principal components (PCs) that discriminated among sensory attributes.

PCA was performed on individual participant overall acceptability scores to illustrate the discrimination among rice samples. Hierarchical clusters analysis (HCA) with squared Euclidean distance and Ward's criterion was carried out using SPSS 12.0.1 (SPSS Inc., Chicago, USA) to investigate the existence of homogeneous clusters of participants with similar overall acceptability for all six rice samples. For each separate cluster, overall acceptability was analysed using repeated measures ANOVA (HSD test) with rice samples as a fixed factor and participant as random factor. In addition, the participant clusters were compared in terms of demographic data using an approximate chi-square test for similarity among groups.

3. Results

3.1 Consumer questionnaire

Ninety-one Auckland rice consumers completed the questionnaire and demographics at both testing locations. (Table 1) Around 25% more females (n=57) than males (n=34), around 27% more "Europeans and others" (n=58) than "East Asians" (n=33) were interviewed. No significant difference in age and rice consumption (frequency and the amount of rice consumed per week) was observed by gender. The East Asian consumers were around 10 years younger than the Europeans and other ethnic consumers (F-value = 11.346, P-value = 0.001). Average East Asian consumers ate 3-fold more rice than Europeans and others per week (F-value = 68.587, P-value < 0.001). Around 30% more participants (in both genders and both ethnic groups) consume refined or white rice than wholegrain or brown rice regularly. Almost half the participants commonly consume freshly boiled or steamed rice while only few participants consume reheated rice. Around 57% East Asian

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consumers preferred freshly boiled or steamed rice while more than half of Europeans and others consumers preferred stir-fried rice. Generally, around 10% more participants preferred rice meals from restaurants or take-away stores.

Table 1 Demographics of interviewed rice consumers (N=91) at Auckland Akoranga (Northshore area) and City centre area.

Demographic variables	**Total** (N=91)	**Gender**		**Ethnic group**[1]	
		Male (n=34, 37.4%)	**Female** (n=57, 62.6%)	**Europeans and others** (n=58, 63.7%)	**East Asians** (n=33, 36.3%)
Average age (years, 95%CI)	38.9 (35.9, 41.9)	39.4(35.1,43.8)	38.6(34.5,42.7)	42.5(38.5, 46.6)	32.6(29.3, 35.9)
Age group (n, %)					
18-35 years	45 (49.5%)	14 (41.2%)	31 (54.4%)	22 (37.9%)	23 (69.7%)
36-55 years	33 (36.3%)	16 (47.1%)	17 (29.8%)	25 (43.1%)	10 (30.3%)
56 over	13 (14.2%)	4 (11.7%)	9 (15.8%)	11 (19.0%)	0 (0%)
Average time per month consumer eats rice (n, 95%CI))	19.0 (15.5, 22.5)	21.4(15.9, 27.0)	17.6(13.0,22.2)	10.7(8.6,12.8)	33.6(27.1,40.2)
Times per month consumer eats rice (n, %)					
4-10	34 (37.4%)	8 (23.5%)	26 (45.6%)	32 (55.2%)	2 (6.1%)
11-20	22 (24.2%)	9 (26.5%)	13 (22.8%)	17 (29.3%)	5 (15.2%)
20+	35 (38.5%)	17 (50.0%)	18 (31.6%)	9 (15.5%)	26 (78.8%)
Amount of cooked rice consumed per month (grams)[2]	2850 (2330, 3380)	3210 (2380 ,4050)	2640 (1950 ,3330)	1610 (1300 ,1910)	5050 (4060 ,6030)
Commonly consumed rice types (n, %)[3]					
Refined, white	60 (65.9%)	23 (67.6%)	37 (64.9%)	39 (67.2%)	21 (63.6%)
Wholegrain, brown	31 (34.1%)	11 (32.4%)	20 (35.1%)	19 (32.8%)	12 (36.4%)
Parboiled	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Common Cooking method (n, %)					
Boiled or steamed freshly	42 (46.2 %)	16 (47.1%)	26 (46.6%)	23 (39.7%)	19 (57.6%)
Stir-fried	35 (38.5%)	14 (41.1%)	21 (36.8%)	30 (51.7%)	5 (15.2%)
Boiled or steamed freshly and reheated [4]	14 (15.4%)	4 (11.8%)	10 (17.5%)	5 (8.6%)	9 (27.3%)
Where consumer prepare rice (n, %)					
Home prepared	38 (41.8%)	13 (38.2%)	25 (43.9%)	23 (39.7%)	15 (45.5%)
Restaurant and take-away	53 (58.2%)	21 (61.8%)	32 (56.1%)	35 (60.3%)	18 (54.5%)

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Note:

[1] All ethnicities were self-identified. "Europeans and others" ethnic group includes New Zealand Pakeha, Maori, and Pacific ethnicities. Two Maori and three Pacific participants were interviewed. East Asian ethnic group includes Chinese, Korean and Japanese.

[2] The amount of rice consumed each time was estimated by "cups of cooked rice consumed x estimated amount (g) per cup".

[3] Commonly consumed rice is defined as the rice that are consumed more than 50% of the time.

[4] Reheated rice was described as cooked rice that has been stored for no more than 24 hours and reheated before consumption.

3.2. Descriptive method

Descriptive sensory attributes texture, flavour, and sweetness discriminated significantly among rice samples (Table 2). The average liking of colour was not significantly different among the six rice samples (F = 1.574, P = 0.167, eta2 = 0.003). Freshly cooked medium grain brown, reheated parboiled, and reheated medium grain brown rice samples scored similarly on overall acceptability which was significantly higher than for freshly cooked white rice.

Table 2 Participants (N = 64) liking score (mm out of 100mm) for colour, texture, flavour and sweetness and overall acceptability of each cooked plain rice sample.

Rice sample	Liking of the attributes [1,2] (mean (mm) (95% CI))				Overall acceptability[1,2]
	Colour	Texture	Flavour	Sweetness	Mean (mm)(95% CI)
Freshly cooked parboiled rice	59.1 (53.8, 63.1)	55.2 (49.8, 60.6)	50.6 (44.9, 56.3)[a]	48.8 (43.1, 54.6)[a]	52.8 (46.9, 58.7)
Freshly cooked medium grain brown rice	60.1 (55.0, 65.2)	58.0 (52.9, 63.1)[a]	59.2 (54.2, 64.2)[b]	50.9 (45.7, 56.2)[a]	57.9 (52.6, 63.3)[a]
Freshly cooked medium grain white rice	59.1 (54.1, 64.2)	46.3 (40.0, 52.5)[b]	43.1 (37.5, 48.8)[a]	42.9 (37.1, 48.7)[b]	44.1 (38.1, 50.2)[b]
Reheated parboiled rice	61.3 (56.1, 66.4)	52.5 (46.3, 58.6)	57.2 (51.6, 62.8)[b]	54.3 (48.4, 60.2)[a]	56.2 (50.4, 61.9)[a]
Reheated medium grain brown rice	60.9 (55.7, 66.0)	52.1 (46.0, 58.2)	56.8 (51.2, 62.4)[b]	53.9 (48.1, 59.8)[a]	55.8 (50.2, 61.5)[a]
Reheated medium grain white rice	58.6 (54.4, 62.8)	47.8 (42.5, 53.1)[b]	45.3 (39.5, 51.1)[a]	42.0 (36.2, 47.7)[b]	50.8 (45.4, 56.1)
Total	59.7 (57.5, 61.7)	52.0 (49.6, 54.3)	52.0 (49.7, 54.4)	48.8 (46.4, 51.2)	52.9 (50.6, 55.3)

Note:

[1] Liking score is presented as mean (mm) (lower 95% CI, upper 95% CI of the mean). The highest score is 100 mm.

[2] The value with the different letter indicates that their mean values are significantly different (P < 0.05) in the same column among six rice samples by repeated measures ANOVA.

Principal component analysis was used to explore the association the rice sample varieties on the liking of sensory attributes of cooked rice. First (PC1) and second (PC2) principal components accounted for 98% of the variance (Table 3), of which 79% was explained by the PC1 and 19% by the PC2. Liking of colour, flavour, sweetness and colour were loaded positively on PC1 and texture and colour on PC2 (Figure 1). Positive, highly significant correlations was found between the liking of

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sweetness and flavour (r = 0.925, P < 0.001). No correlation was found between the liking of colour and texture (r = 0.271).

Reheated parboiled rice and freshly cooked medium grain brown rice samples received higher liking scores on all four sensory attributes compared to other rice samples. These two rice samples were similar to one another on scores for liking of flavour and sweetness. However, participants showed higher liking of texture in freshly cooked medium grain brown rice than in reheated parboiled rice, and higher liking of colour in reheated parboiled than in freshly cooked medium grain brown rice. Overall, the cold storage and reheating treatment had more significant effect on parboiled rice than other rice varieties. The post-cooking treatment significantly improved the liking of colour, flavour and sweetness of parboiled rice whilst reducing the texture. However, while the same post-cooking treatment significantly reduced texture scores and improved colour scores for medium grain brown rice, there was a minimal effect on flavour and sweetness. Both reheated and freshly cooked medium grain white rice samples had significantly lower scores for liking on the four sensory attributes compared to other samples. The liking scores for flavour and sweetness were similar between these two medium grain white rice samples. However, the cold storage and reheating treatment reduced the colour and texture of medium grain white rice.

Table 3 Principal component factor loading from principal component analysis (PCA) showing the liking of four sensory attributes and percentage variance accounted for by the first two components (PC1 and PC2)

Sensory	Factor loading	
Liking of attributes	**PC1**	**PC2**
Colour	0.814*	-0.570*
Texture	0.770*	0.635*
Flavour	0.988*	0.082
Sweetness	0.969*	-0.109
% Variance	79	19

Note: * Factor loading with an absolute value greater than 0.50 or less than -0.50 represent a strong correlation.

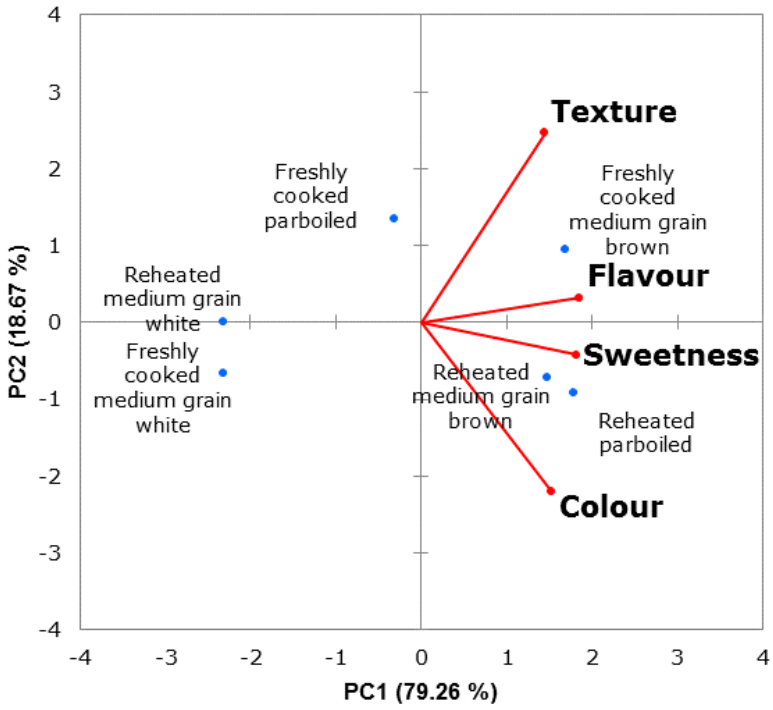

Figure 2 Scores plot for principal component analysis of the six rice samples evaluated by consumers for overall acceptability.

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238 *3.3 Acceptability of rice samples*

239 The individual overall acceptability by 64 participants interviewed varied and is illustrated in
240 the principal component plot ((Figure 3), which accounts for 61.6% of the variability, with 39.6%
241 explained by PC1 and 21.9% by PC2. The low level of explained variance could be due to the
242 participants not being able to differentiate between freshly cooked and reheated rice samples [9].
243 However, more participants were positioned in the upper part of the map in the direction of freshly
244 medium grain brown rice and along the direction of reheated parboiled and reheated medium grain
245 brown rice (Table 4, Figure 3, and Figure 4). Few participants had strong acceptability for the freshly
246 cooked medium grain white rice. (Figure 4, lower right quarter).

247 **Table 4** Overall acceptability results from principal component analysis (PCA) showing the 6 rice
248 samples scores and percentage variance accounted for by the first two components

	Principal components		
Rice sample	PC1	PC2	PC3
Freshly cooked parboiled rice	0.422	0.660*	-0.093
Freshly cooked medium grain brown rice	-0.079	0.931*	-0.585*
Freshly cooked medium grain white rice	0.052	-0.092	0.884*
Reheated parboiled rice	0.973*	0.025	-0.034
Reheated medium grain brown rice	0.973*	0.024	-0.034
Reheated medium grain white rice	0.422	-0.059	0.202
% Variance	39.6	21.9	19.6

249 Note: * Factor loading with an absolute value greater than 0.50 or less than -0.50 represent a strong correlation.

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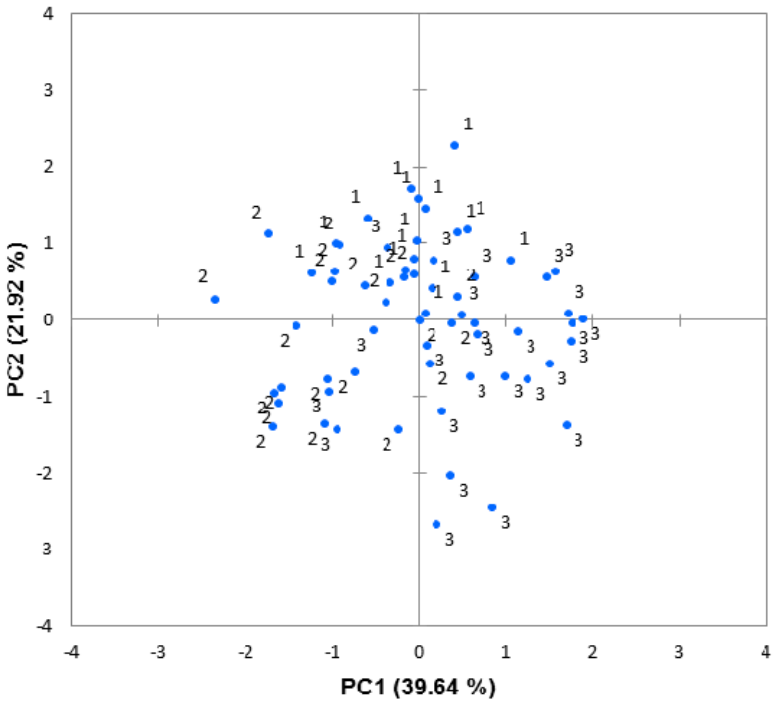
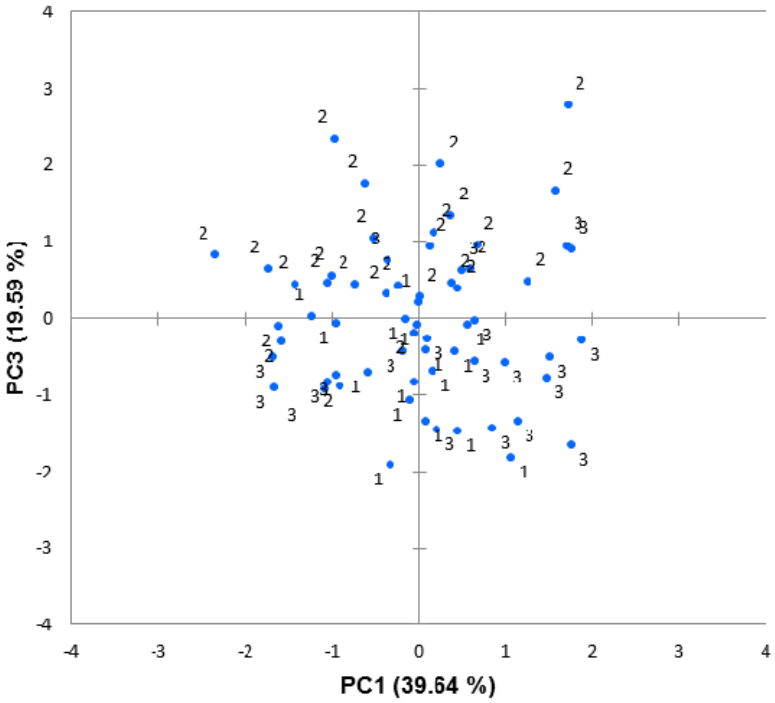


(a)



(b)

Figure 3 Correlation loadings plot from principal component analysis ((a): PC1 and PC2; (b): PC1 and PC3) with clustered consumer overall acceptability cluster 1, 2 and 3.

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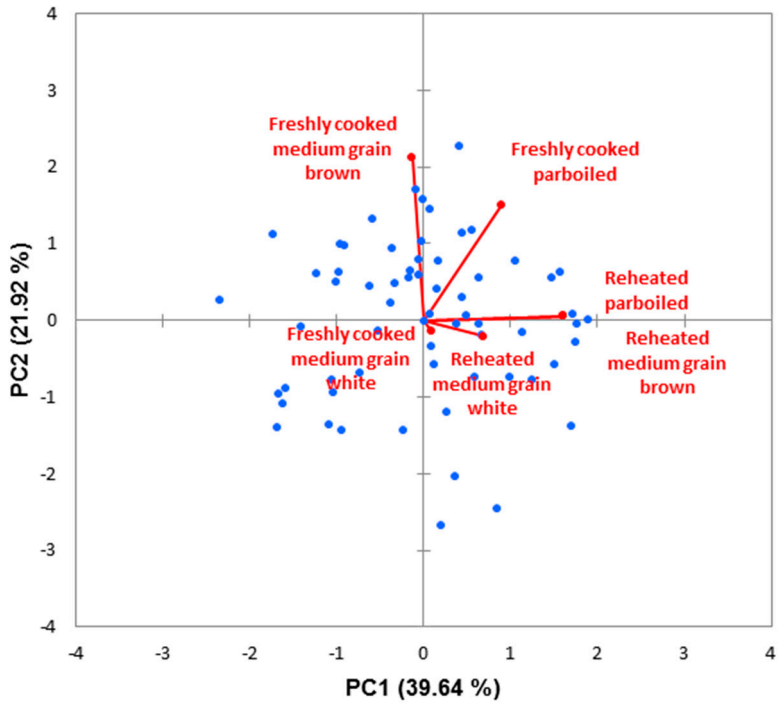
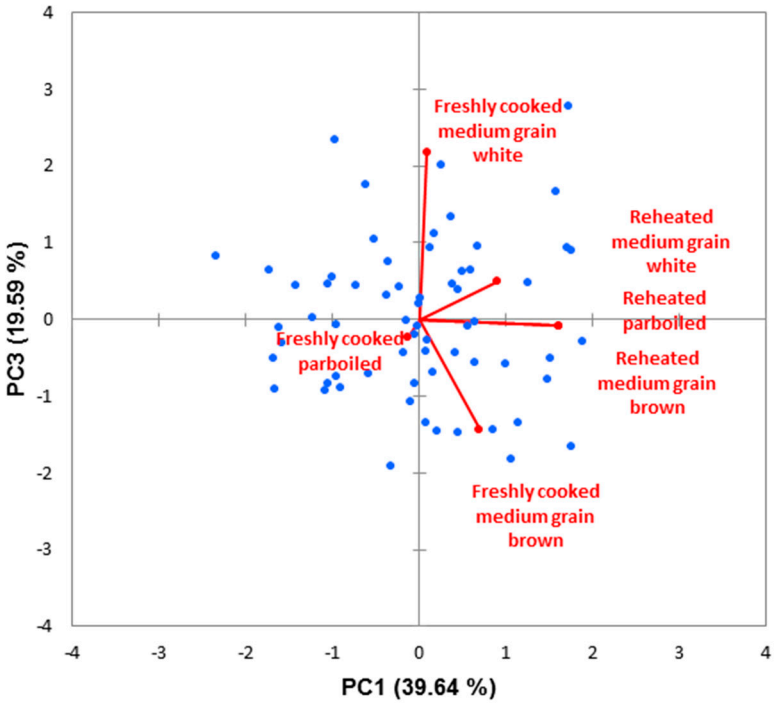


254 (a)



255 (b)

256 **Figure 4** Scores plot from principal component analysis of the six rice samples evaluated by
257 consumers for overall acceptability ((a): PC1 and PC2; (b): PC1 and PC3).

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Table 5 Mean VAS score (mean, 95% confidence interval) of overall acceptability scores for each cluster including overall mean acceptability

Rice sample	Cluster 1 (n=14)	Cluster 2 (n=14)	Cluster 3 (n=36)	Overall (N=64)
Freshly cooked parboiled rice	74.7 (64.6, 84.8)[a]	51.4 (42.8, 60.0)[a]	40.5 (32.6, 48.4)[a]	52.8 (47.1, 58.5)
Freshly cooked medium grain brown rice	61.8 (50.8, 72.9)[bd]	56.0 (46.6, 65.4)[a]	57.2 (48.5, 65.8)[bc]	57.9 (52.2, 63.7)
Freshly cooked medium grain white rice	25.4 (14.3, 36.5)[c]	55.8 (46.3, 65.2)[a]	45.8 (37.1, 54.5)[ac]	44.1 (38.4, 49.9)
Reheated parboiled rice	56.1 (47.9, 64.3)[b]	34.7 (27.7, 41.7)[b]	74.3 (67.9, 80.7)[b]	56.2 (50.4, 61.9)
Reheated medium grain brown rice	55.7 (47.6, 63.9)[b]	34.5 (27.6, 41.4)[b]	73.8 (67.4, 80.2)[d]	55.8 (50.0, 61.5)
Reheated medium grain white rice	64.7 (54.7, 74.6)[abd]	39.9 (31.4, 48.4)[b]	51.5 (43.6, 59.3)[ac]	50.8 (45.1, 56.5)
F-value	18.83	6.48	10.42	2.97
P-value	<0.001	<0.001	<0.001	0.012

Note:

[1] Acceptability score is presented as mean (mm) (lower 95% CI, upper 95% CI of the mean). The highest score is 100 mm.

[2] The value with the different letter indicates that their mean values are significantly different ($P < 0.05$) in the same column among three clusters by repeated measures ANOVA.

HCA identified three clusters of similar overall acceptability of the six rice samples. The three clusters consisted of 21.9% (n=14), 21.9% (n=14), and 56.3% (n=36) participants, respectively. PC1 separated participants in cluster 3 from cluster 1 and 2, while PC2 separated participants in cluster 1 from the other two clusters. (Figure 3). For each cluster, ANOVA results showed that consumers significantly differentiated among the rice samples (Table 5). Participants tended to prefer the medium grain brown rice and parboiled rice, both freshly cooked and reheated. However, cluster 2 participants tended to prefer freshly cooked rice samples, whilst cluster 3 participants preferred reheated ones. Participants in cluster 1 preferred the freshly cooked parboiled and medium grain brown rice to reheated counterparts, however, they significantly favoured the reheated medium grain white rice over reheated samples.

Demographic characteristics and rice consumption habits were compared among three clusters. Cluster 3 comprised two-thirds of the adults between 36 and 55 years while participants in other two clusters were much younger (18 to 35 years). Most participants in cluster 1 consumed rice meals less than 10 times per month (75%), while those in cluster 2 (79%) and 3 (84%) consumed more than 10 times per month. Participants in cluster 1 and 3 were predominantly European (over 85%) and in cluster 2 were East Asian (78.2%). More participants in cluster 3 commonly ate both brown rice (58.2%) and white rice (41.8%) prepared at home (63.8%), while the other two clusters reported that they ate white rice (62.5% and 68.2% respectively) at restaurant or from takeout (68.8% and 72.7% respectively). As a result, cluster 1 is characterised as younger Europeans who occasionally eat white rice at a restaurant or takeout, cluster 2 as younger Asian consumers who regularly eat white rice at a restaurant or takeout. Cluster 3, the largest cluster, is middle aged consumers from both ethnic groups who commonly consume both brown rice and white rice in a home-cooked meal.

4. Discussion

Overall, reheated parboiled rice was rated favourably in terms of colour, sweetness and flavour and could be accepted as an alternative to freshly cooked or reheated medium grain white rice. In addition to liking based on sensory attributes, the favourable glycaemic properties of reheated parboiled rice [1,2], provides evidence that reheated parboiled rice could be recommended for a healthier diet. Previous studies have observed overall acceptability of rice over 5.0 on average for

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freshly cooked using a 10-point categorical Likert scale (1 = extremely dislike and 10 = extremely like) [7,15], which is consistent with the present result. The present study has demonstrated the feasibility of a longer-term dietary intervention involving consumption of the parboiled rice and adoption of safe cold-storage and reheating post-cooking treatment in a multi-ethnic population [2].

The overall acceptability ratings of parboiled rice and medium grain brown rice were higher than medium grain white rice samples when consumed freshly-cooked or reheated. This trend was associated with the higher liking of all four attributes (i.e. texture, flavour, sweetness, and colour) of both medium grain brown rice and parboiled rice, in which rice sensory profiles are mostly formed during process-induced changes (i.e. polishing and parboiling pre-treatment) [8]. The higher total lipids deposition on the surface of brown rice bran (60 to 80% higher compared to polished white rice) undergoes lipase and subsequent oxidation and is hydrolysed to free fatty acids to produce a distinct colour and flavour [16]. Polyphenols in rice bran may also be associated with a bitter or astringent taste [17]. The bran residue increases the total dietary fibre content and gives the cooked brown rice a nutty texture [18]. Mixed rice acceptability ratings have been observed in previous studies. Muhihi, *et al.* [19] reported whole grain brown rice as highly acceptable among overweight and obese Tanzania adults in terms of smell, taste, colour, appearance, and texture. However, the studies in Costa Rica [20], China [21], and South India [22] reported that the local consumers preferred polished white rice and the major barriers for accepting whole grain brown rice were chewy and nutty texture, poor appearance (colour), and distinct flavour. Although no study has investigated the consumers' acceptability of whole grain rice verses refined grain rice in Western countries, a number of studies have reported that European consumers (in United Kingdom, Italy, Finland, and Germany) favoured wholegrain cereal and wheat products [23,24] due to a high awareness of the health-related information of the wholegrain products. This is consistent with the present findings which reported New Zealand European participants preferred wholegrain to white rice while East Asian participants preferred the opposite.

After parboiling and polishing, parboiled rice loses the bran and crude fat content, however, soaking at high temperature during parboiling makes parboiled rice retain coloration, nutty, chewy texture, and some distinct flavour [25]. Present findings are consistent with previous studies which observed that white rice and parboiled rice samples presented comparable levels of appearance [7,26] and whiteness was less important in quality perception of rice products [7,27]. More recent studies in India by Sudha, Spiegelman, Hong, Malik, Jones, Wedick, Hu, Willett, Bai, Ponnalagu, Arumugam and Mohan [22] and Kumar, *et al.* [28] also reported parboiled rice was favoured by participants compared with brown rice, because its appearance and aroma after polishing represented higher quality. The present study also reported European participants, compared to Asian, had a higher acceptability of parboiled rice. This could be associated with Europeans' liking of nutty and pigmented whole grain rice.

Cold storage and reheating preparation significantly improved participants' liking of flavour and sweetness of parboiled rice. Liking of sweetness is significantly correlated with the liking of flavour. Decreased sweetness and flavour might be due to reduced starch digestibility after cold-storage and reheating (i.e. increased proportion of resistant starch and slowly digested starch) [1,2], with less oral hydrolysis and consequently decreased oral sugar release. Decreased sweetness in rice also contributed to a healthier image of rice meals [26, 28, 29]. Previous studies in India [28,30] found that participants generally preferred grains that were less sweet and with less creamy flavour.. However, studies in East Asia [21,31] found that participants preferred increased sweetness and creamier flavour in refined grain. As the present study recruited around 25% of East Asian origin and 75% of European and South Asian origins, the increase in overall acceptability, flavour and sweetness could be attributed to the differences in the liking preference between ethnic groups from which the participants in the present study were drawn (Hori et al., 1994; Prescott, 1998).

Cold storage and reheating only slightly improved the liking of the texture of medium grain white rice, while it reduced the liking of the texture of parboiled and medium grain brown rice. It is suggested that cold storage and reheating reduced the moisture content and increased the gelatinised starch recrystallization in medium grain white rice, as was observed in previous *in vitro* studies of

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starch digestibility in rice [1], and might have reduced the grain adhesion and increased hardness, resulting in an increased liking of the texture [26] as the firmer texture was generally favoured by participants of European and South Asian origin [19,28,30]. However, the decrease in adhesion and softness during storage is higher for long grain rice (i.e. high amylose parboiled rice) [8] in which the cold storage may have increased firmness resulting in reduced liking of the texture. Similarly, cold storage of whole grain brown rice might have resulted in significantly firmer texture with bran intact, therefore, it may result in significantly firmer texture.

Food habits and culture could play a significant role in accepting parboiled and brown rice products and the optimisation of reheating method in some ethnic groups [7,19,21,27,29,32]. Both Chinese [21] and Costa Rican studies [20] reported that participants perceived brown rice as a less accepted product in terms of taste, quality, family tradition, and social status. Kumar, Mohanraj, Sudha, Wedick, Malik, Hu, Spiegelman and Mohan [28] and Sudha, Spiegelman, Hong, Malik, Jones, Wedick, Hu, Willett, Bai, Ponnalagu, Arumugam and Mohan [22] also suggested that consumers tend to prefer the rice product that has been consumed by the family for generations. Similarly, Behrens et al. [32] and Heinemann [7] suggested the lack of the knowledge of the nutritional aspects of parboiled rice and the unfamiliarity with parboiled rice could reduce the acceptability among rice consumers. Consumer's prior experience with a product might influence the liking and acceptability [33]. The present study confirmed the hypothesis that participants who prepare and consume brown rice at home regularly (more than 10 times per month), preferred the reheated brown rice and parboiled rice compared to the participants who consume white rice regularly. Acceptance of healthier rice choices may be improved by nutrition and health education of the potential health benefits and nutritional value (i.e. glycaemic lowering effect) of parboiled and brown rice, and knowledge of the method for cooking them.[20-22].

However, neither nutritional information alone is able to impact on rice consumers' acceptability of parboiled and brown rice, nor knowledge of the reheating method. A recent review by Heiniö, Noort, Katina, Alam, Sozer, de Kock, Hersleth and Poutanen [29] suggested that preference for the sensory attributes (i.e. colour, odour, texture, and flavour) in refined grains could contribute to the reasons of lower acceptability of whole grain cereals. The results of the present study, which compared sensory characteristics of reheated parboiled rice and other samples, support the claim that higher acceptability contributes to healthier and more sustainable diets.

The design and execution of the study followed the requirements for a reliable and credible laboratory-based sensory liking test [9] which was powered to detect minimal difference in the VAS ratings given for the rice sample [9,34]. The other advantage of this study is that the selection of participants was not designed to have an even number of participants in each age, gender and ethnic group but the participant population may represent the diverse Auckland community who eat rice. All participants were asked to fast for at least two hours before testing and rinse their mouth thoroughly between testing of each sample in order to avoid possible misjudging or bias. The other strength of this study is the novelty of the study design. No recent study has examined the effect of a home-prepared cold storage and reheating treatment on the sensory attributes of rice (overall acceptability, colour, texture, flavour and sweetness).

The main limitation of this study is that it compared medium-grain white, medium-grain brown and parboiled rice only once with a relatively small number of participants. Previous studies have introduced a multi-sample repeated measure on one participant on separate days in order to minimise the Type II error [9]. It is suggested that a repeated measure be introduced to test within-individual variance. In addition, only five attributes, colour, flavour, texture, sweetness, and overall acceptability were compared, and other factors, such as mood and when last eaten, that may have influenced participants' liking, were not measured. Because this study was not designed to compare the age, gender and ethnic effect on liking preference, these factors were not compared. There may be a natural variation in preference in different population groups [9].

5. Conclusions

These findings corroborate the need for marketing efforts that can effectively inform about the health advantages of overnight cold storage and reheating and the nutritional values and convenience of parboiled rice. This information may contribute to increasing public awareness and, eventually, bringing the nutritional benefit to the population.

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