Consumer Acceptance of Brown and White Rice Varieties

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Abstract

Rice is consumed as a staple food by more than half of the world's population. Due to a higher fibre and micronutrient content, brown rice is more nutritious than white rice, but the consumption of brown rice is significantly lower than that of white rice, primarily due to sensory attributes. Therefore, the present research aimed to identify the sensory attributes which drive liking of Australian-grown brown and white rice varieties. Participants (n = 139) tasted and scored (9-point hedonic scale) their liking (i.e., overall liking, aroma, colour and texture) of brown and white rice types of Jasmine (Kyeema), Low GI (Doongara) and Medium grain rice (Amaroo). In addition, participants scored, aroma, colour, hardness, fluffiness, stickiness and chewiness, on Just About Right Scales. A within-subjects crossover design with randomised order (William's Latin Square design) was used with six repeated samples for liking and Just About Right scales. Penalty analyses were applied to determine the relative influence of perception of sensory attributes on consumer liking of the rice varieties. Across all varieties, white rice was liked more than brown rice due to texture and colour, and Jasmine rice was preferred over Low GI and Medium Grain. Rice texture (hardness and chewiness) was the most important sensory attribute among all rice varieties and aroma was important for driving of liking between white rice varieties.

1. Introduction

Rice is consumed as a staple food by more than 4 billion people around the globe (Lee, Sreenivasulu, Hamilton, & Kohli, 2019; Sattari, Mahdinezhad, Fakheri, Noroozi, & Beheshtizadeh, 2015; Younas et al., 2020). Rice is a significant source of dietary nutrients such as carbohydrates, vitamins and minerals (Civáň, Craig, Cox, & Brown, 2015; Huang et al., 2012). For populations that rely on rice as a staple food, it delivers approximately 21% of the consumed energy and 15% of the consumed protein (Maclean, Dawe, Hardy, & Hettel, 2002).

Australia produces high quality rice from different varieties, which are categorised as aromatic-Thai jasmine origin and non-aromatic rice (Chaudhary, Tran, & Duffy, 2001). Aromatic rice varieties have distinctive popcorn like flavour notes due to the presence of 2-acetyl-1-pyrroline (Bryant & Mcclung, 2011; R. G. Buttery, Ling, & Mon, 1986; Chaudhary et al., 2001; Daygon et al., 2017). Furthermore, rice can be classified based on the milling process. The milling of the whole grain results in brown rice, a further removal of bran and germ, results in white rice. (IRRI, 2013). Although white rice is more commonly consumed, brown rice is considered healthier due to nutritional components such as lipids, proteins, dietary fibre and polyphenols (Mir, Bosco, Shah, & Mir, 2016; Tikapunya, Henry, & Smyth, 2018).

The sensory profile of rice is an important driver of consumer acceptance. Sensory attributes have a strong influence on product selection, consumption and purchase decisions (Combris, Bazoche, Giraud-Héraud, & Issanchou, 2009; Januszewska, Pieniak, & Verbeke, 2011). Sensory attributes such as physical appearance (i.e., uniformity, cleanliness, brightness, glossiness and translucency of the rice grain) (Tomlins, Manful, Larwer, & Hammond, 2005), taste (e.g., sweetness, bitterness) and aroma (e.g., floral notes) are drivers of liking (Li, Jervis, & Drake, 2015) that affect consumer acceptance of rice.

Furthermore, rice texture (i.e., cohesiveness, softness) has been suggested to be of high importance for consumer acceptance of rice. A previous study reported that brown rice texture was less liked compared to white rice and there was variation in liking of the various textures of different brown rice varieties (Kwon & Ju, 2018). Along the same lines, Suwansri et al suggested that an increase in hardness of rice is associated with a lower consumer acceptability (Suwansri, Meullenet, Hankins, and Griffin, 2002). The importance of texture has also been emphasised by Maleki et al, who suggests that consumers can be segmented based on their preference for different rice textures (Maleki, Oliver, Lewin, Liem, & Keast, 2020).

Within each rice variety, the milling process (e.g., white vs brown rice) alters the nutrient composition and sensory attributes (Shobana et al., 2011) For example, brown rice has a higher lipid content compared with white rice. The lipid context affects the sensory profile due to lipid oxidation in the bran layer of brown rice (Park, Kim, & Baek, 2010). Lipid oxidation leads to the development of off-flavours (Pingret, Fabiano-Tixier, & Chemat, 2013), which potentially impact consumer perception and acceptance. In short, differences in the acceptance of white and brown rice is likely caused by differences in sensory profiles, which are related to differences in nutrient composition (Sudha et al., 2013).

In Australia 90% of rice is consumed as white rice, whereas only 10% is consumed as brown rice (Pollard et al., 2017), which is similar to global rice consumption patterns (Pollard et al., 2017; Selvam, Masilamani, Umashankar, & Albert, 2017).. To understand what drives the difference in consumption of brown and white rice it is important to investigate the sensorial differences of brown and white rice.

The objective of this study is to identify the drivers of liking of Australian-grown brown and white rice varieties. It will provide important information for rice industry and breeding programmes for the development of new rice varieties to meet consumer needs.

2. Participants, Materials And Methods

2.1 Study design:

A within-subjects crossover design with randomised order (William's Latin Square design) for liking and Just About Right scales with six repeated samples was used in the present study. To determine the required participant sample size, G*power [Version 3.1.9.2, (Franz Faul) Germany 2014] was used. Based on six measurements (six rice samples) comparisons within subjects with alpha level 0.05, power of 0.8, and a small effect size (f=.10), the minimum sample size was 109. To account for potential dropouts, 140 participants from CASS Food Research Centre database were recruited. Participants were excluded if they had food allergies, dietary restrictions, and/or were pregnant or lactating. Participants were asked to refrain from eating, drinking or brushing their teeth one hour prior to testing. The rice consumer study was approved by the research ethics committee Deakin University (HEAG-H 29_2018).

2.2 Measurements:

Participants were asked to complete two questionnaires concerning 1) demographics (age, gender, education, and marital status), and 2) rice consumption (type of rice (brown or white), number of times they eat rice daily, weekly or fortnightly, and awareness of brown rice health benefits). To assess the liking and sensory perception of the rice samples before and after tasting the rice samples, participants filled out 9-point hedonic scales (9= extremely like and 1= extremely dislike) (Peryam & Pilgrim, 1957) for overall liking, aroma, colour and texture. In addition, participants completed Just About Right scales for aroma intensity, colour, hardness, fluffiness, stickiness and chewiness. A Just About Right scale, is a bipolar labelled attribute scale (Pagès, Berthelo, Brossier, & Gourret, 2014), which has an anchored mid-point that corresponded to Just About Right for each attribute (Cadot, Caillé, Samson, Barbeau, & Cheynier, 2010). The Just About Right scales provided the participants with 3 answer options per sensory attribute (1=not enough, 2= Just about Right, 3= too much) (J.-E. Yang & Lee, 2020).

2.3 Materials:

Three Australian rice varieties [Jasmine rice (Kyeema), Low GI (Doongara) and Medium grain (Amaroo) (Table 1)] with both brown and white rice types were sourced from Sunrice (Ricegrowers Ltd, Leeton, Australia) Australia.

Rice samples were washed 2 to 3 times in cold running water until the water ran clear. Rice samples were cooked in dedicated rice cookers ("Grain Master" HD4514/72_ UM_ US_v1.0, Philips), to avoid cross flavour contamination, according to manufacturer's instructions with specific water to rice ratios (Table 1). Rice samples and water quantities were measured by a measuring cup. Rice was cooked at quick rice cooking mode and kept warm in the rice cooker for no longer than the duration of the sensory test (approximately 45 minutes).

2.4 Testing procedure:

Sensory testing took place in a sensory laboratory, which consisted of partitioned booths and a high-capacity air filtration system, of the CASS Food Research Centre, Deakin University Melbourne, Australia. On arrival participants were instructed to carefully read the Plain Language Statement and sign the consent form. Ten participants participated in each one-hour session. Rice samples were served to the participants in 30 mL serving cups that were labelled with three-digit unique codes. The rice samples were randomly presented one at a time directly from the rice cooker at a temperature of 55 ±3 ^{o}C. The participants were instructed to rinse their mouth with filtered water for five seconds and use crackers between tasting the different rice samples.

The test consisted of two parts (i.e., before tasting, after tasting). In the first part, the participants received the following instruction: “do not eat the rice samples, only look, feel (e.g., hold the rice between your fingers) and smell the rice”. Next, participants were asked to rate overall liking and their liking for aroma and colour on a 9-point hedonic scale, and fluffiness, stickiness, hardness and aroma intensity on Just About Right Scales.

In the second part, the participants were instructed to taste the rice samples (one by one) and rate on 9-point hedonic scales, their overall liking, and texture for each rice sample. In addition, participants rated their perceived intensity of flavour, fluffiness, hardness and chewiness on Just About Right scales. There was a one-minute break after the tasting of each sample to avoid tasting fatigue of the participants.

The data was collected on computers using Compusense Software Academic Consortium (Compusense, Inc., Guelph, Ontario, Canada). Gift vouchers were served to each participant on completion of the rice consumer test.

2.5 Statistical Analysis:

All rice consumer study data was exported from Compusense Cloud into Microsoft Excel version 1708 (Microsoft Corporation) for data cleaning. For the statistical analysis of liking, the program Stata/IC 15.0 (StataCorp LLC,4905 Lakeway Drive, College Station, Texas 77845, USA) was used. Descriptive statistics (mean, standard deviation and correlation coefficient) were calculated for overall liking scores and all sensory attributes. Box plots and scatter plots were extracted for overall liking and for other sensory attributes. Linear mixed model approach was used to analyse repeated measure Analysis of Variance (ANOVA) data to determine the effect of rice varieties (Jasmine, Low GI and medium grain rice samples) and rice types (brown, white) on overall liking, aroma, colour and texture linking. This approach accounts for within subjects autocorrelation via a random intercept in the model. The combined effect of rice varieties and types of rice was tested through a model that contained main effects of rice type (brown and white) and varieties (Jasmine, Low GI and Medium Grain) as well as the two-way interaction between varieties, and types of rice. The post-hoc pairwise comparison (Bonferroni adjusted) was conducted to identify the significant difference in sensory attributes among rice varieties and rice types.

The descriptive statistics for Just About Right attributes, overall liking and penalty analysis ($p<0.05$) of brown and white rice from the three varieties was conducted in XLSTAT-Sensory version 2020.3 (Addinsoft, New York, NY, USA). The penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together (J.-E. Yang & Lee, 2020). Spearman’s correlation coefficients were calculated. Mean drop plots were extracted to identify the effect of JAR attributes on overall liking of rice. The mean drops were plotted against the percentage of consumers. For penalty analysis and mean drop plots, 20% consumers were considered as threshold level for each JAR attribute (Pagès et al., 2014).

3. Results

3.1 Participants

The participants (n=140, female 52%, male 48%) from different age groups participated in the consumer study, one participant was excluded during data cleaning because of incomplete rice tasting session. The participants were rice consumers and mostly thought they were aware of the health benefits of brown rice. The demographics are shown in table 2.

3.2 Liking (9-point hedonic scale) of brown and white rice varieties before tasting:

In the result section rice variety refers to the different varieties which were tested (i.e., Jasmine white, Jasmine brown, Low GI white, Low GI brown, Medium grain white and Medium grain brown) and rice type refers to brown and white rice. The results (Table 3) indicate that there was a main effect of rice varieties and their types (i.e., brown vs white) on overall liking before tasting the rice samples ($p<0.05$). However, there was no statistically significant interaction between rice variety (i.e., Jasmine, Low GI, Medium Grain) and rice type. That is, white rice was preferred over brown rice, regardless of the rice variety ($p<0.05$) (see Figure 1). Pairwise comparisons show that Jasmine white rice was more liked than any of the other rice varieties ($p<0.05$). While, liking of Low GI white and Med. grain was not statistically significantly different (represented with shared letter “C”). Likewise, no difference was observed between the overall liking of brown rice varieties.

For aroma liking, there was a significant difference (Table 3) between rice varieties and their types (i.e., brown vs white) before tasting the rice samples. The differences in mean values of Low GI and Medium Grain were -0.6, 95% CI (-0.8, -0.5) and -0.7, 95% CI (-0.9, -0.5) respectively when compared with Jasmine rice (a reference sample). The interaction between rice variety (i.e., Jasmine, Low GI, Medium Grain) and rice type was also statistically significant. That is, the aroma of white rice was preferred over brown rice, regardless of the rice variety ($p<0.05$) (see Figure 1). Pairwise comparisons show that the aroma of Jasmine white rice was more liked than any of the other rice varieties (i.e., Jasmine white rice has the highest mean 7.0, 95% CI (6.9, 7.3) and Medium Grain brown has lowest mean 5.8, 95% CI (5.5, 6.1)). While, liking of Low GI white and Med. grain was not statistically significantly different (represented with shared letter “AB”). Similarly, no difference was observed between the aroma liking of Low GI and Med. Grain brown rice varieties.

The rice varieties and their types (i.e., brown vs white) were significantly associated with colour liking before tasting the rice samples. The differences in mean values of Low GI and Medium Grain for colour liking were -0.4, 95% CI (-0.5, -0.2) and -0.1, 95% CI (-0.3, -0.04) respectively when compared with Jasmine rice (a reference sample). However, the interaction between rice variety (i.e., Jasmine, Low GI, Medium Grain) and rice type was not statistically significant. That is, the colour of white rice was liked more than the colour of brown rice, regardless of the rice variety (see Figure 1). Pairwise comparisons show that there was no difference in colour liking of Jasmine white and Med. Grain white rice (represented with shared letter “C”). Likewise, no difference was observed in colour liking of Jasmine brown, Low GI brown and Med. Grain brown (represented with shared letter “A”).

3.2.1. Liking (9-point hedonic scale) of brown and white rice varieties after tasting:

The results show rice variety and rice type (i.e., brown and white) after tasting significantly affect liking (see Table 4). Jasmine rice was liked more than Low GI and Medium Grain rice. For all rice varieties white rice was preferred over brown rice (mean difference= 0.8, 95% CI (0.6, 1.1). The significant interaction between rice varieties and rice types (i.e., brown and white) shows that Jasmine white rice was liked more than any of the other brown and white rice varieties (see Figure 1). The pairwise comparisons show that no difference was observed between Low GI white rice, Med. Grain white rice and Jasmine brown rice in overall liking after tasting.

There was significant correlation between rice variety and rice type on texture liking ($p<0.05$) after tasting rice samples (Table 4). That is, the texture of Jasmine rice was liked more than the texture of Low GI and Medium Grain. The mean liking of Low GI and Medium Grain rice were reduced by -0.6, 95% CI (-0.8, -0.4) and -0.4, 95% CI (-0.7, -0.2) respectively when compared with Jasmine rice (a reference sample). Likewise, the texture of white rice was preferred over brown rice, regardless of rice varieties (mean difference=0.91, 95% CI (0.6, 1.2). The significant interaction between rice varieties and rice types also indicates that the texture of Jasmine white rice was liked more than the texture of any of the other brown and white rice varieties (see Figure 1). The pairwise comparisons show that no difference was observed between Low GI white rice, Med. Grain white rice and Jasmine brown rice in texture liking after tasting. However, the texture liking of brown rice varieties was not statistically different.

3.3. Just About Right attributes and Penalty Analysis

3.3.1. Penalty analysis of Jasmine brown and white rice before tasting:

Penalty analysis shown in Table 5, indicates that the overall penalty is significant ($p<0.05$) for all attributes of Jasmine brown rice. This means that the rice was not perceived at optimum level for all attributes tested. The Jasmine brown rice was rated as being too low in aroma, too dark in colour, too hard in texture, too low in fluffiness and/or too low in stickiness. Similarly, for Jasmine white rice, the overall penalty (Table 5) is not significant for any of the attributes. This means that across all tested attributes, a deviation from JAR did not have a significant influence on overall liking. The mean drop plot against consumers for each attribute of Jasmine brown and white rice shown in Figure 2 (A & B), which visually represents the results of the penalty analysis.

3.3.2. Penalty analysis of Low GI brown and white rice before tasting:

The overall penalty analysis for Low GI brown rice is significant ($p<0.05$) for all attributes except “hardness” ($p=0.18$) (see table 6). This means that the hardness of Low GI brown rice was the only attribute which was rated as being optimal. The penalty analysis (Table 6) shown that the overall penalty for Low GI white rice is significant for fluffiness ($p<0.05$). This means that the rating of liking was significantly negatively influenced when participant rated Low GI white as low in fluffiness. Specific changes in liking due to suboptimal attributes are shown in Figure 3 (A & B) which visually represents the penalty analysis of Low GI rice.

3.3.3. Penalty analysis of Med. Grain brown and white rice before tasting:

The results of the penalty analysis (Table 7) for Med. Grain brown rice show that the overall liking was significantly ($p<0.05$) influenced when majority of the participants considered aroma, colour and hardness are not at optimum level, the attributes were too high in aroma, too dark in colour and too hard in texture. Similarly, the overall penalty (Table 7) for Med. Grain white rice is significant for fluffiness ($p=0.02$). That means, for fluffiness, the deviations from the Just about right level have significant impact on overall liking. The impact on liking of each attribute shown in Figure 4(A & B).

3.3.4 Penalty analysis of Jasmine brown and Jasmine white rice after tasting:

Penalty analysis (Table 8) indicate that the overall liking was significantly ($p<0.05$) influenced when participants rated the Jasmine brown rice as not being ideal for flavour, fluffiness, hardness or chewiness. For Jasmine white rice, the overall penalty (Table 8) is only significant for hardness and not significant for all other attributes after rice tasting. This means that most of the participants considered Jasmine white rice “not hard enough” in texture. The mean drop plot against participants for each attribute by tasting of Jasmine brown and Jasmine white rice shown in Figure 5(A & B).

3.3.5 Penalty analysis of Low GI brown and Low GI white rice after tasting:

The penalty analysis (Table 9) of Low GI brown rice by tasting shows that the overall liking was significantly ($p<0.05$) influenced when most of the participants judged that flavour, hardness and fluffiness were not optimal in Low GI brown rice. For Low GI white rice, the overall penalty (Table 9) is significant ($p<0.05$) for all attributes tested. This means, the overall liking was significantly influenced, when majority of the participants rated Low GI white rice as being not ideal for flavour, fluffiness, hardness or chewiness. The influence on liking of sensory attributes shown in Figure 6(A & B).

3.3.6 Penalty analysis of Med. Grain brown and white rice after tasting:

For Med. Grain brown rice, the penalty analysis (Table 10) shows that the overall liking of Med. Grain brown rice was significantly ($p<0.05$) influenced when participant rated flavour, fluffiness and hardness were not at optimum level. Similarly, the overall penalty of Med. Grain white rice is significant for flavour intensity, fluffiness and chewiness. This means that significant participants perceived Med. Grain white as too low in flavour and fluffiness, and too high in chewiness. The mean drop plots against participants for each attribute of Med. Grain brown rice shown in Figure 7(A & B).

4. Discussion

This study aimed to identify the consumer liking, sensory attributes, and drivers of liking of brown and white rice varieties. The results suggest that, overall, participants liked Jasmine rice varieties more than Low GI and Medium grain rice varieties. This was also reflected in a higher liking of the aroma, colour and texture of Jasmine rice, compared to Low GI and Medium grain rice varieties. However, white rice is preferred over brown rice regardless of rice varieties.

The present study suggests, in line with previous studies (Bunyasiri & Sirisupluxana, 2017; Sudha et al., 2013; Suwansri et al., 2002; Wangcharoen et al., 2016) that texture, colour and aroma are important drivers of consumer liking for rice. However, these drivers of liking do not seem to equally explain the differences in liking of white and brown rice. That is, differences in aroma mainly explain the difference in liking for white rice varieties and the aroma of Jasmine white rice was liked more than any of the other rice varieties. The most liked white rice (Jasmine rice), contains more of the compound 2-acetyle-1-pyrroline (Daygon et al., 2017) which is known to elicit a distinctive popcorn/pandan aroma (Bergman et al., 2000; Ron G Buttery, Ling, Juliano, & Turnbaugh, 1983; Jezussek, Juliano, & Schieberle, 2002; Lee et al., 2019) that has strong impact on consumer acceptance of rice (Tananuwong & Lertsiri, 2010). Whereas the other white rice (non-fragrant) varieties contain less 2AP (Mahattanatawee & Rouseff, 2014; D. S. Yang, Shewfelt, Lee, & Kays, 2008; Zeng, Zhang, & Zhang, 2009) that may have an impact on liking of non-fragrant white rice varieties. This is also reflected in the sensory data of the present study that aroma of Jasmine white rice is an important sensory attribute in predicting consumer liking and acceptance of white rice varieties. Therefore, the aroma of Jasmine white rice was preferred over all other white and brown rice varieties. In contrast to aroma being able to explain liking differences for white rice varieties, aroma does not fully explain differences in liking for brown rice.

Differences between brown rice varieties can be explained by texture (hardness and chewiness). That is, brown rice is considered as too hard and chewy in texture which is driving the difference between brown rice varieties. Whereas Jasmine brown rice was preferred over Low GI and Med. grain brown rice. However, the results are in line with previous study conducted on ready to eat rice in Korea that the brown rice was scored less in overall acceptability due to being high in hardness, chewiness and yellowness (Kwon & Ju, 2018). Brown rice hardness in texture is associated with dietary fibre that is present in bran layer (Wang et al., 2011) whereas, in white rice, polishing removes bran and germ during rice processing (Liu, Zheng, & Chen, 2017). This significantly improves texture liking and consumer acceptance of white rice. However, the current study investigated consumer acceptance of brown and white rice with Western consumers using 9-Point hedonic scales, JAR scales and penalty analysis that was not reported by previous studies. This study also compared a range of brown and white rice varieties which enabled to compare brown and white rice, but also identify the drivers of liking between brown rice varieties as well as the drivers of liking within white. In addition, Therefore, it is interesting to note that rice texture (hardness) is more important for the consumer acceptance and overall liking of Australian brown rice varieties. This study suggests that the decrease in hardness and chewiness will increase the overall liking of Australian brown rice varieties, which can eventually increase brown rice acceptance and consumption.

Brown rice texture (hardness and chewiness) and colour are the sensory attributes that are driving the difference between white and brown rice varieties. That is, the texture of brown rice is less liked as compare to white rice regardless of rice varieties, because the majority of participants rated brown rice varieties as too hard and too chewy. However, differences in texture seem to be more important when comparing liking between white and brown rice. This is in line with study conducted on consumer acceptance of parboiled brown and white rice reported that white rice was preferred to brown rice because of texture and colour (Sudha et al., 2013). The results are also in agreement with the study that reported consumer acceptance of white rice varieties in Thailand, the participants preferred cooked white rice because of the soft texture (Wangcharoen et al., 2016). Suwansri and Meullenet (2004) reported that Asian consumers preferred rice with white appearance (colour) and less sticky texture (Suwansri & Meullenet, 2004). Similarly, the consumers from South Asia and Middle East did not prefer brown rice texture (Suwannaporn, Linnemann, & Chaveesuk, 2008). In the present study, the sensory results also suggest that brown rice texture (hardness and chewiness) is the most important sensory attribute that is driving the liking and consumer acceptance of brown rice.

This study has several strengths as this is the first study that focused on consumer acceptance of Australian brown and white rice varieties. In addition, sensory attributes for consumer acceptance were evaluated using 9-point hedonic scale, Just About Right scale and penalty analysis was also conducted in this study. However, there are some limitations that need to be addressed. The participants were mainly living in urban areas and were well educated, with 79% of participants holding undergraduate degree or higher. That may affect their liking because of their awareness to the brown and white rice varieties which may cause bias in evaluation of rice attributes. For future investigation, the sample (participants) could be recruited from different geographical areas to predict the preference of Australian brown and white rice varieties. Future studies are suggested with more focus on texture attributes of brown rice. To identify the variability in texture of brown rice, different cooking methods and water to rice ratios are recommended. In addition, the instrumental analysis (colour and texture analyser) can be considered for the better understanding of texture attributes of brown and white rice varieties.

5. Conclusion

Texture is the most important sensory attribute which explains the difference in liking between brown and white rice. Whereas differences in aroma, best explain variation in liking of white rice. Therefore, the sensory attributes of Australian brown rice varieties can be improved by the development of new rice varieties which are soft in texture. Future research is needed to investigate if an increased water absorption, milling process, packaging and storage of brown rice can positively improve the texture and subsequently increase consumer acceptance.

Abbreviations

JAR: Just About Right

IRRI: International Rice Research Institute

CASS: Centre for Analytical Sensory and Safety

ANOVA: Analysis of Variance

XLSTAT: Name of Statistical Sensory Software

CI: Confidence Interval

Ref: Reference

Declarations

Ethics approval and consent to participate

The rice consumer study was approved by the research ethics committee Deakin University (HEAG-H 29_2018). The participants were asked to read Plain Language Statement (PLS) and all participants signed their consent forms.

Consent for publication

The written consent for publication from all authors has been received.

Availability of supporting data

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

Tanweer Aslam Gondal: Conceptualization, Methodology, Writing, and original draft preparation. **Russell Keast:** Conceptualization, Supervision, Reviewing and Editing. **Robert A Shellie:** Writing- Reviewing and Editing. **Snehal R Jadhav:** Supervision, Writing- Reviewing and Editing. **Shirani Gamlath:** Supervision, reviewing and editing. **Mohammadreza Mohebbi:** statistical analysis**. Djin Gie Liem:** Conceptualisation, Methodology, Supervision, Writing- Reviewing and Editing.

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Tables

Table 1: Selected Australian rice varieties.

Rice Varieties	Samples (Types)	Water to Rice ratio
Jasmine (Kyeema)	Brown rice	2 : 1
Jasmine (Kyeema)	White rice	1.5 : 1
Low GI (Doongara)	Brown rice	2 : 1
Low GI (Doongara)	White rice	1.5 : 1
Medium grain (Amaroo)	Brown rice	2 : 1
Medium grain (Amaroo)	White rice	1.5 : 1

Table 2: Demographics of the participants for rice tasting study.

	Demographics	Participants
Age groups	Age 18-30 years	56%
	Age 31-45 years	28%
	Age 46 years and above	16%
Rice consumers	Brown rice	10%
	White rice	37%
	Brown and white rice	53%
Brown rice health benefits _ perceived knowledge	Aware enough	67%
	Not aware enough	33%
Education	High school certificate/ Diploma	21%
	Bachelor and above	79%

Table 3: Linear mix model (repeated measures) ANOVA table for brown and white rice varieties before tasting

Overall liking				Aroma liking			Colour liking		
	Mean (95% CI)	Mean diff. (95 % CI)	Chi-square (df) p value	Mean (95% CI)	Mean diff. (95 % CI)	Chi-square (df) p value	Mean (95% CI)	Mean diff. (95 % CI)	Chi-square (df) p value
Rice variety									
Jasmine	6.6 (6.4, 6.8)	Ref.	26.50 (2) *P* <0.0001	6.7 (6.5, 6.9)	Ref.	53.84 (2) *P* ≤0.0001	6.6 (6.4, 6.8)	Ref.	20.08 (2) *P* ≤0.0001
Low GI	6.2 (6.0, 6.4)	-0.5 (-0.7, -0.3)**		6.1 (5.9, 6.3)	-0.6 (-0.8, -0.5)**		6.2 (6.1, 6.5)	-0.4 (-0.5, -0.2)**	
Med. Grain	6.3 (6.1, 6.5)	-0.3 (-0.5, -0.1)**		6.1 (5.9, 6.3)	-0.7 (-0.9, -0.5)**		6.5 (6.3, 6.7)	-0.1 (-0.3, -0.04)	
Rice type									
Brown	5.9 (5.6, 6.2)	Ref.	45.50 (1) *P* <0.0001	6.1 (5.8, 6.3)	Ref.	13.93 (1) *P* ≤0.0002	5.9 (5.6, 6.2)	Ref.	50.85 (1) *P* ≤0.0001
White	6.9 (6.7, 7.0)	1.0 (0.7, 1.2)**		6.5 (6.3, 6.7)	0.5 (0.2, 0.7)**		7.0 (6.9, 7.3)	1.2 (0.9, 1.5)**	
Pairwise comparisons of variety and rice type (Bonferroni groups)			Overall liking by variety and rice type interaction	Pairwise comparisons of variety and rice type (Bonferroni groups)		Overall liking by variety and rice type interaction	Pairwise comparisons of variety and rice type (Bonferroni groups)		Overall liking by variety and rice type interaction
Jasmine White	7.2 (6.9, 7.4)	D	1.69	7.0 (6.9, 7.3)	D	6.94	7.3 (7.1, 7.5)	C***	1.21
Low GI White	6.7 (6.5, 6.9)	C***	(2) *P*= 0.43	6.2 (5.9, 6.4)	AB***	(2) *P*=0.03	6.9 (6.7, 7.1)	B	(2) *P* =0.55
Med. Grain White	6.7 (6.5, 7.0)	C		6.3 (6.1, 6.6)	AB		7.0 (6.9, 7.2)	BC	
Jasmine	6.1	B		6.4 (6.1, 6.7)	B		6.0 (5.7, 6.3)	A	

Brown	(5.8, 6.4)						
Low GI Brown	5.7 (5.3, 6.0)	A		6.0 (5.7, 6.3)	AB	6.0 (5.7, 6.3)	AB
Med. Grain Brown	5.9 (5.6, 6.2)	AB		5.8 (5.5, 6.1)	A	5.8 (5.5, 6.1)	A

** p 0.001 (p<0.05), ** p 0.000 (p<0.001), **** The pairs that share alphabet letter are not statistically significantly different

Table 4: Mix model (repeated measures) ANOVA table for brown and white rice varieties after tasting

Overall liking				Texture liking		
	Mean (95% CI)	Mean diff. (95 % CI)	Chi-square (df) p value	Mean (95% CI)	Mean diff. (95 % CI)	Chi-square (df) p value
Rice variety						
Jasmine	6.5 (6.3, 6.8)	Ref.	47.59 (2) *P* ≤0.0001	6.3 (6.1, 6.6)	Ref.	25.67 (2) *P* ≤0.0001
Low GI	5.9 (5.6, 6.1)	-0.7 (-0.9, -0.5)**		5.7 (5.5, 6.1)	-0.6 (-0.8, -0.4)**	
Med. Grain	6.0 (5.8, 6.2)	-0.6 (-0.8, -0.4)**		5.9 (5.6, 6.1)	-0.4 (-0.7,-0.2)*	
Rice type						
Brown	5.7 (5.4, 6.0)	Ref.	37.45 (1) *P* ≤0.0001	5.5 (5.2, 5.8)	Ref.	35.25 (1) *P* ≤0.0001
White	6.6 (6.4, 6.8)	0.8 (0.6, 1.1)**		6.4 (6.2, 6.6)	0.91 (0.6, 1.2)**	
Pairwise comparisons of variety and rice type (Bonferroni groups)			Overall liking by variety and rice type interaction	Pairwise comparisons of variety and rice type (Bonferroni groups)		Overall liking by variety and rice type interaction
Jasmine White	7.0 (6.7, 7.3)	D	0.28	6.8 (6.5, 7.1)	D	1.11
Low GI White	6.3 (6.0, 6.5)	B	(2) *P*=0.87	6.2 (5.9, 6.5)	C	(2) *P*=0.57
Med. Grain White	6.4 (6.2, 6.7)	B		6.3 (6.0, 6.6)	C	
Jasmin Brown	6.1	B		5.8 (5.5, 6.1)	BC	

	(5.8, 6.4)				
Low GI Brown	5.5 (5.2, 5.8)	A		5.3 (5.0, 5.6)	A
Med. Grain Brown	5.5 (5.2, 5.9)	A		5.5 (5.1, 5.8)	AB

p 0.001 (p<0.05), ** p 0.000 (p<0.001), ** The pairs that share alphabet letter are non-significant

Table 5. The Penalty analysis and JAR variables (before tasting) for Jasmine brown and white rice

Rice	Attribute	Sensory test	Correlation coefficient[a]	Level	Selection%[b]	Mean[c]	Mean drop[d]	Penalty[e]
Jasmine Brown	Aroma	Smell	0.12	Too low	17.99	5.28	1.25	
				JAR	53.24	6.53		0.85**
				Too high	28.78	5.93	0.60	
	Colour	Visual	-0.35	Too light	10.79	5.87	1.0	
				JAR	51.08	6.87		1.52*
				Too dark	38.13	5.21	1.67	
	Hardness	Handling	-0.22	Not hard enough	13.67	6.0	0.62	
				JAR	52.52	6.62		1.03*
				Too hard	33.81	5.43	1.19	
	Fluffiness	Handling	0.16	Too low	35.97	5.70	0.81	
				JAR	48.20	6.50		0.73**
				Too much	15.83	5.96	0.55	
	Stickiness	Handling	0.01	Too low	13.67	5.0	1.57	
				JAR	49.64	6.57		0.87 **
				Too much	36.69	5.96	0.60	
Jasmine White	Aroma	Smell	0.02	Too low	20.86	7.24	-0.05	
				JAR	48.92	7.19		0.08
				Too high	30.22	7.02	0.17	
	Colour	Visual	-0.09	Too light	17.27	7.25	-0.06	
				JAR	70.50	7.19		0.15
				Too dark	12.23	6.77	0.43	
	Hardness	Handling	-0.12	Not hard enough	28.06	7.41	-0.27	
				JAR	61.87	7.14		-0.30
				Too hard	10.07	6.50	0.64	
	Fluffiness	Handling	0.13	Too low	17.99	7.08	-0.05	
				JAR	65.47	7.03		-0.34
				Too much	16.55	7.70	-0.66	
	Stickiness	Handling	-0.04	Too low	2.88	8.0	-0.72	
				JAR	41.01	7.28		0.22
				Too much	56.12	7.01	0.27	

[a]The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman's correlation coefficient with a significance level a= 0.05). The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes have impacted ("low" or "high") on overall liking for rice samples. When the correlation is positive, the "too little" has a bigger impact than the "too much", and vice-versa for the negative correlations. If correlation is "0" for a JAR attribute then that attribute would have a strong impact on overall liking (XLSTAT, 2021)

[e]Penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together

*$p \leq 0.001$, **$p \leq 0.05$

Table 6. The Penalty analysis and JAR variables (before tasting) for Low GI brown and white rice

Rice	Variable	Sensory test	Correlation coefficient[a]	Level	Selection%[b]	Mean[c]	Mean drop[d]	Penalty[e]
Low GI Brown	Aroma	Smell	-0.15	Too low	24.46	5.79	0.22	
				JAR	43.88	6.02		0.63**
				Too high	31.65	5.07	0.95	
	Colour	Visual	-0.38	Too light	15.83	5.68	0.87	
				JAR	46.04	6.55		1.64*
				Too dark	38.13	4.59	1.96	
	Hardness	Handling	-0.18	Not hard enough	12.23	5.94	-0.04	
				JAR	44.60	5.90		0.44
				Too hard	43.17	5.33	0.57	
	Fluffiness	Handling	0.14	Too low	41.01	5.33	0.68	
				JAR	43.88	6.01		0.63**
				Too much	15.11	5.52	0.49	
	Stickiness	Handling	0.16	Too low	28.06	4.90	1.22	
				JAR	48.92	6.12		0.89**
				Too much	23.02	5.63	0.49	
Low GI White	Aroma	Smell	0.06	Too low	31.65	6.66	-0.09	
				JAR	46.76	6.57		-0.22
				Too high	21.58	6.97	-0.40	
	Colour	Visual	0.08	Too light	14.39	6.25	0.53	
				JAR	73.38	6.78		0.34
				Too dark	12.23	6.65	0.13	
	Hardness	Handling	0.02	Not hard enough	12.95	6.78	-0.11	
				JAR	61.15	6.67		-0.03
				Too hard	25.90	6.67	0.004	
	Fluffiness	Handling	0.17	Too low	18.71	6.0	0.88	
				JAR	65.47	6.88		0.57**
				Too much	15.83	6.68	0.20	
	Stickiness	Handling	0.06	Too low	19.42	6.37	0.41	
				JAR	61.15	6.78		0.24
				Too much	19.42	6.70	0.07	

[a]The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman's correlation coefficient with a significance level a= 0.05. The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes have impacted ("low" or "high") on overall liking for rice samples. When the correlation is positive, the "too little" has a bigger impact than the "too much", and vice-versa for the negative correlations. If correlation is "0" for a JAR attribute then that attribute would have a strong impact on overall liking (XLSTAT, 2021)

[e]Penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together

*$p \leq 0.001$, **$p \leq 0.05$

Table 7. The Penalty analysis and JAR variables (before tasting) for Med. grain brown and Med. grain white rice

Rice	Variable	Sensory test	Correlation coefficient[a]	Level	Selection%[b]	Mean[c]	Mean drop[d]	Penalty[e]
Med. Grain Brown	Aroma	Smell	-0.11	Too low	22.30	5.65	0.85	
				JAR	39.57	6.49		0.96**
				Too high	38.13	5.47	1.02	
	Colour	Visual	-0.44	Too light	8.63	5.83	1.02	
				JAR	48.92	6.85		1.84*
				Too dark	42.45	4.85	2.01	
	Hardness	Handling	-0.39	Not hard enough	4.32	6.0	0.70	
				JAR	41.01	6.70		1.34*
				Too hard	54.68	5.32	1.39	
	Fluffiness	Handling	0.12	Too low	33.09	5.61	0.59	
				JAR	44.60	6.19		0.51
				Too much	22.30	5.81	0.39	
	Stickiness	Handling	0.07	Too low	24.46	5.21	1.18	
				JAR	50.36	6.39		0.95*
				Too much	25.18	5.66	0.73	
Med. Grain White	Aroma	Smell	0.04	Too low	35.97	6.58	0.28	
				JAR	39.57	6.86		0.21
				Too high	24.46	6.74	0.12	
	Colour	Visual	0.05	Too light	14.39	6.50	0.28	
				JAR	72.66	6.78		0.20
				Too dark	12.95	6.67	0.12	
	Hardness	Handling	0.14	Not hard enough	24.46	6.44	0.30	
				JAR	57.55	6.74		0.26
				Too hard	17.99	7.08	-0.34	
	Fluffiness	Handling	0.08	Too low	23.02	6.34	0.62	
				JAR	54.68	6.96		0.52**
				Too much	22.30	6.55	0.41	
	Stickiness	Handling	-0.13	Too low	7.91	6.64	0.36	
				JAR	37.41	7.0		0.44
				Too much	54.68	6.55	0.45	

[a]The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman's correlation coefficient with a significance level a= 0.05). The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes have impacted ("low" or "high") on overall liking for rice samples. When the correlation is positive, the "too little" has a bigger impact than the "too much", and vice-versa for the negative correlations. If correlation is "0" for a JAR attribute then that attribute would have a strong impact on overall liking (XLSTAT, 2021)

[e]Penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together

*$p \leq 0.001$, **$p \leq 0.05$

Table 8. The Penalty analysis and JAR variables (after tasting) for Jasmine brown and Jasmine white rice

Rice	Variable	Correlation coefficient[a]	Level	Selection%[b]	Mean[c]	Mean drop[d]	Penalty[e]
Jasmine Brown	Flavour	0.02	Too low	25.90	5.83	0.62	
			JAR	53.96	6.45		0.72**
			Too high	20.14	5.61	0.85	
	Fluffiness	0.27	Too low	30.22	5.17	1.45	
			JAR	56.83	6.62		1.15*
			Too much	12.95	6.17	0.45	
	Hardness	-0.26	Not hard enough	8.63	5.25	1.59	
			JAR	54.68	6.84		1.59*
			Too hard	36.69	5.26	1.59	
	Chewiness	-0.20	Too low	8.63	5.67	1.06	
			JAR	46.76	6.73		1.13*
			Too much	44.60	5.58	1.14	
Jasmine White	Flavour	0.20	Too low	30.22	6.69	0.42	
			JAR	52.52	7.11		0.23
			Too high	17.27	7.21	-0.10	
	Fluffiness	0.25	Too low	21.58	6.13	1.04	
			JAR	58.99	7.17		0.42
			Too much	19.42	7.44	-0.27	
	Hardness	0.27	Not hard enough	24.46	6.00	1.37	
			JAR	69.06	7.37		1.18*
			Too hard	6.47	6.89	0.48	
	Chewiness	-0.03	Too low	18.71	6.81	0.34	
			JAR	58.99	7.15		0.36
			Too much	22.30	6.77	0.37	

[a]The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman's correlation coefficient with a significance level a= 0.05. The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes have impacted ("low" or "high") on overall liking for rice samples. When the correlation is positive, the "too little" has a bigger impact than the "too much", and vice-versa for the negative correlations. If correlation is "0" for a JAR attribute then that attribute would have a strong impact on overall liking (XLSTAT, 2021)

[e]Penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together

*$p \leq 0.001$, **$p \leq 0.05$

Table 9. The Penalty analysis and JAR variables (after tasting) for Low GI brown and Low GI white rice

Rice	Variable	Correlation coefficient[a]	Level	Selection%[b]	Mean[c]	Mean drop[d]	Penalty[e]
Low GI Brown	Flavour	-0.16	Too low	33.81	5.55	0.50	
			JAR	39.57	6.06		0.96**
			Too high	26.62	4.51	1.54	
	Fluffiness	0.19	Too low	35.97	5.0	0.83	
			JAR	51.80	5.83		0.74**
			Too much	12.23	5.35	0.48	
	Hardness	-0.33	Not hard enough	5.76	5.38	0.81	
			JAR	35.25	6.18		1.10*
			Too hard	58.99	5.06	1.12	
	Chewiness	0.02	Too low	12.95	5.39	0.01	
			JAR	34.53	5.40		-0.12
			Too much	52.52	5.55	-0.15	
Low GI White	Flavour	0.21	Too low	44.60	5.82	0.92	
			JAR	44.60	6.74		0.89*
			Too high	10.79	6.0	0.74	
	Fluffiness	0.12	Too low	20.86	5.31	1.39	
			JAR	64.03	6.70		1.24*
			Too much	15.11	5.67	1.03	
	Hardness	-0.11	Not hard enough	15.83	5.68	0.97	
			JAR	60.43	6.66		1.02*
			Too hard	23.74	5.61	1.05	
	Chewiness	0.04	Too low	23.02	5.94	0.56	
			JAR	59.71	6.49		0.60**
			Too much	17.27	5.83	0.66	

[a]The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman's correlation coefficient with a significance level a= 0.05). The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes

have impacted (“low” or “high”) on overall liking for rice samples. When the correlation is positive, the “too little” has a bigger impact than the “too much”, and vice-versa for the negative correlations. If correlation is “0” for a JAR attribute then that attribute would have a strong impact on overall liking (XLSTAT, 2021)

*$p \leq 0.001$, **$p \leq 0.05$

Table 10. The Penalty analysis and JAR variables (after tasting) for Med. Grain brown and white rice

Rice	Variable	Correlation coefficient[a]	Level	Selection%[b]	Mean[c]	Mean drop[d]	Penalty[e]
Med. Grain Brown	Flavour	-0.11	Too low	25.18	5.23	1.02	
			JAR	46.76	6.25		1.31*
			Too high	28.06	4.67	1.58	
	Fluffiness	0.34	Too low	33.09	4.35	1.89	
			JAR	53.24	6.24		1.49*
			Too much	13.67	5.74	0.50	
	Hardness	-0.52	Not hard enough	5.04	6.71	0.05	
			JAR	38.85	6.76		1.98*
			Too hard	56.12	4.60	2.16	
	Chewiness	-0.07	Too low	12.95	6.06	-0.62	
			JAR	34.53	5.44		-0.17
			Too much	52.52	5.49	-0.05	
Med. Grain White	Flavour	0.22	Too low	48.20	6.06	0.75	
			JAR	41.01	6.81		0.65**
			Too high	10.79	6.60	0.21	
	Fluffiness	0.13	Too low	23.02	5.75	0.99	
			JAR	58.99	6.74		0.78**
			Too much	17.99	6.24	0.50	
	Hardness	0.11	Not hard enough	5.04	6.29	-0.03	
			JAR	38.85	6.26		-0.27
			Too hard	56.12	6.55	-0.29	
	Chewiness	-0.07	Too low	16.55	6.17	0.53	
			JAR	53.96	6.71		0.61**
			Too much	29.50	6.05	0.66	

[a]The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman’s correlation coefficient with a significance level a= 0.05). The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes have impacted (“low” or “high”) on overall liking for rice samples. When the correlation is positive, the “too little” has a bigger

impact than the “too much”, and vice-versa for the negative correlations. If correlation is “0” for a JAR attribute then that attribute would have a strong impact on overall liking (XLSTAT, 2021)

[e]Penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together

*$p \leq 0.001$, **$p \leq 0.05$

Figures

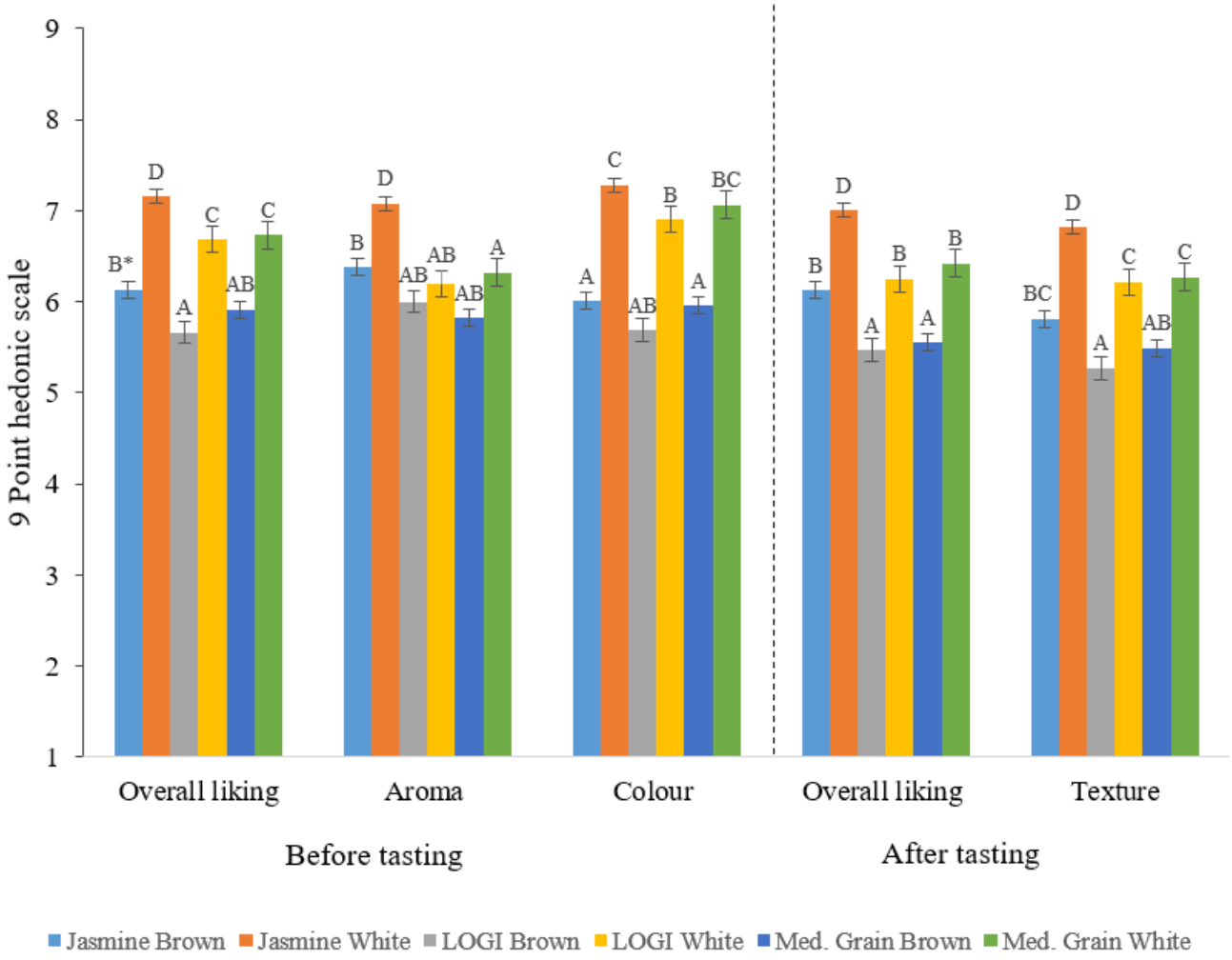

Figure 1

Mean liking (9-point hedonic scale) of sensory attributes for rice varieties *Shared letters within attribute are not statistically significantly different *9-point hedonic scale:1- Extremely Dislike, 9- Extremely like

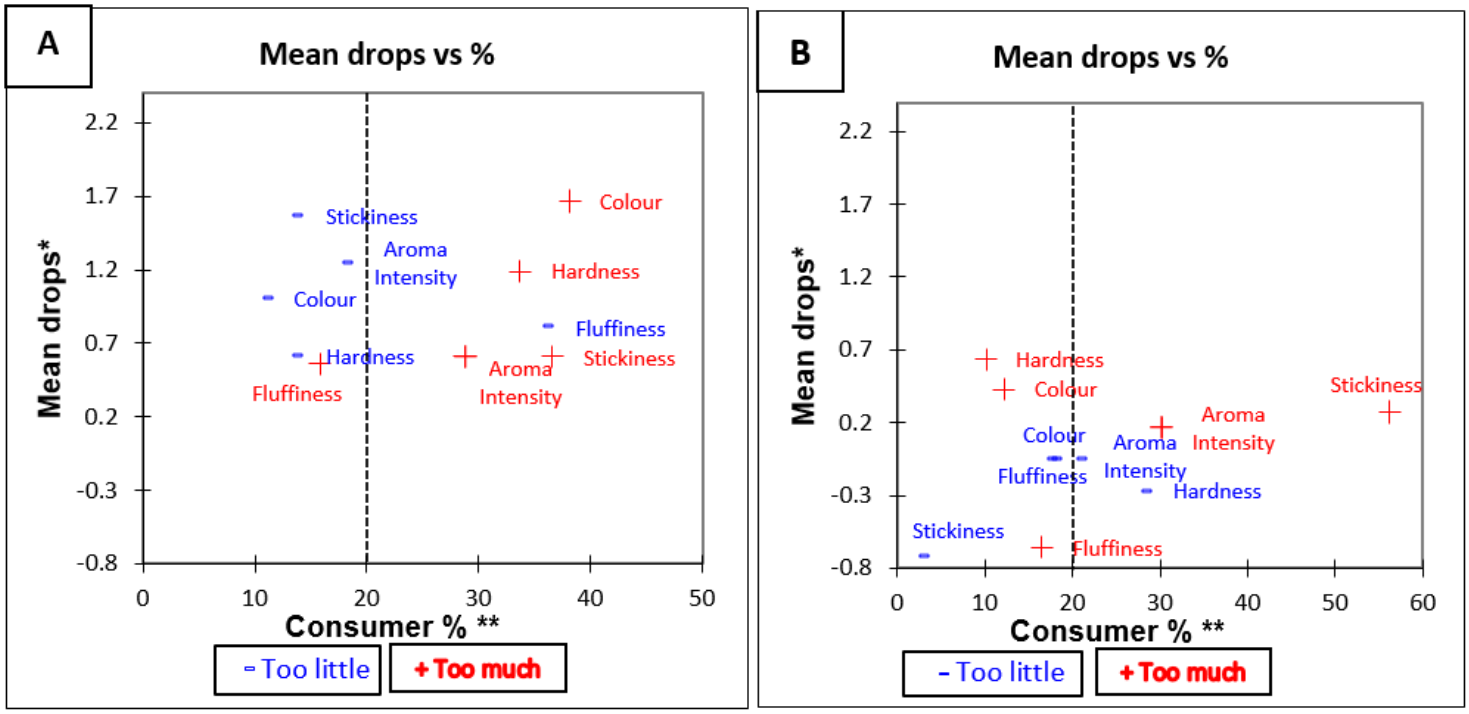

Figure 2

Mean drop plots for Jasmine rice variety before tasting A) Jasmine Brown, and B) Jasmine White * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR **Consumer % are the consumers which judged an attribute as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrate the critical points of the product (Rothman & Parker, 2009).

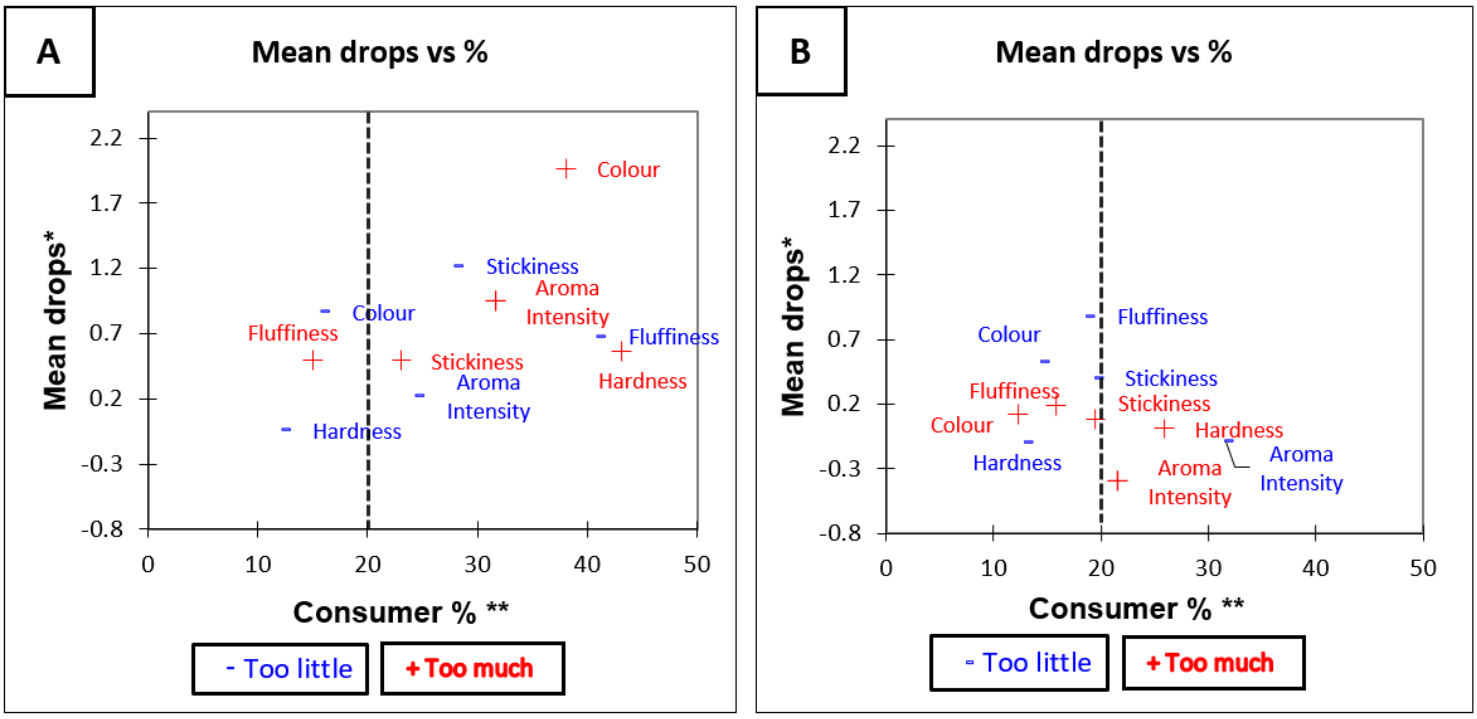

Figure 3

Mean drop plots for Low GI rice variety before tasting A) Low GI Brown, and B) Low GI White * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR **Consumer % are the consumers which judged an attribute

as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrate the critical points of the product (Rothman & Parker, 2009).

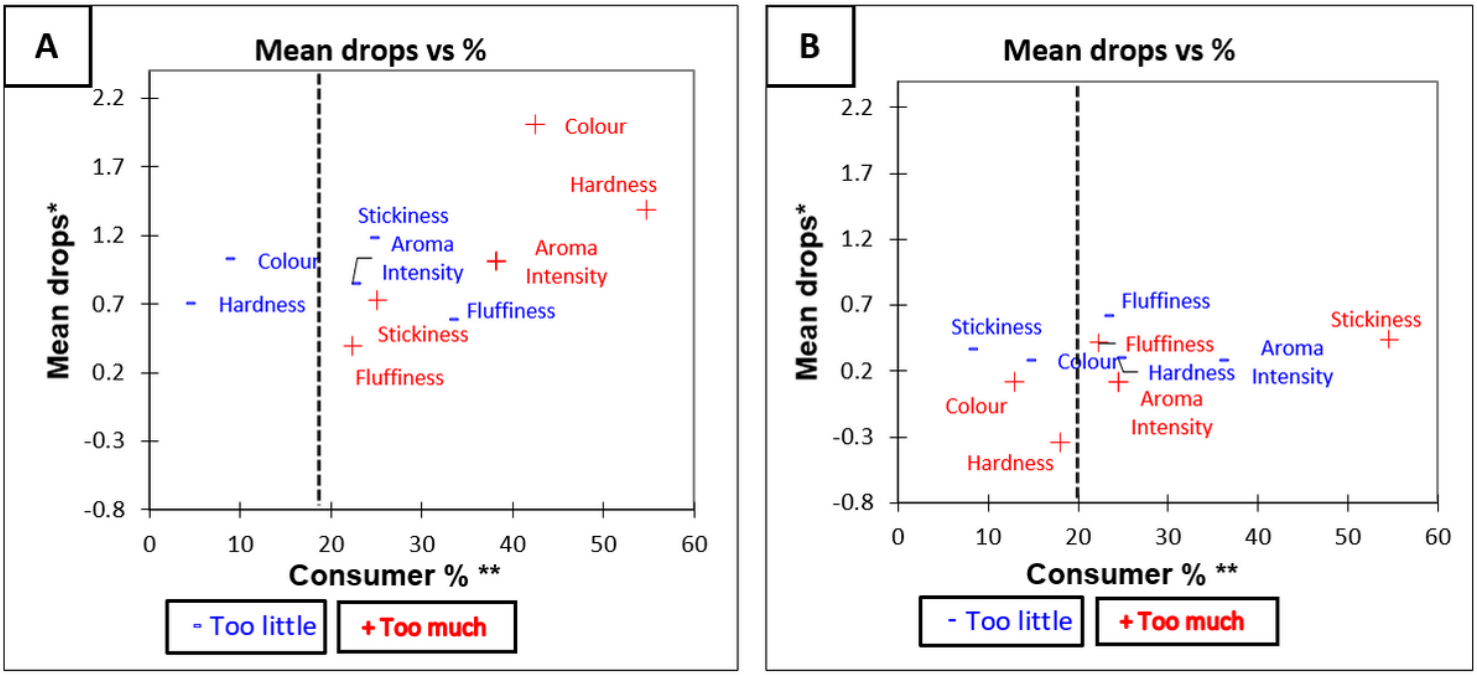

Figure 4

Mean drop plots for Med. Grain rice variety before tasting A) Med. Grain Brown, and B) Med. Grain White * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR **Consumer % are the consumers which judged an attribute as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrate the critical points of the product (Rothman & Parker, 2009).

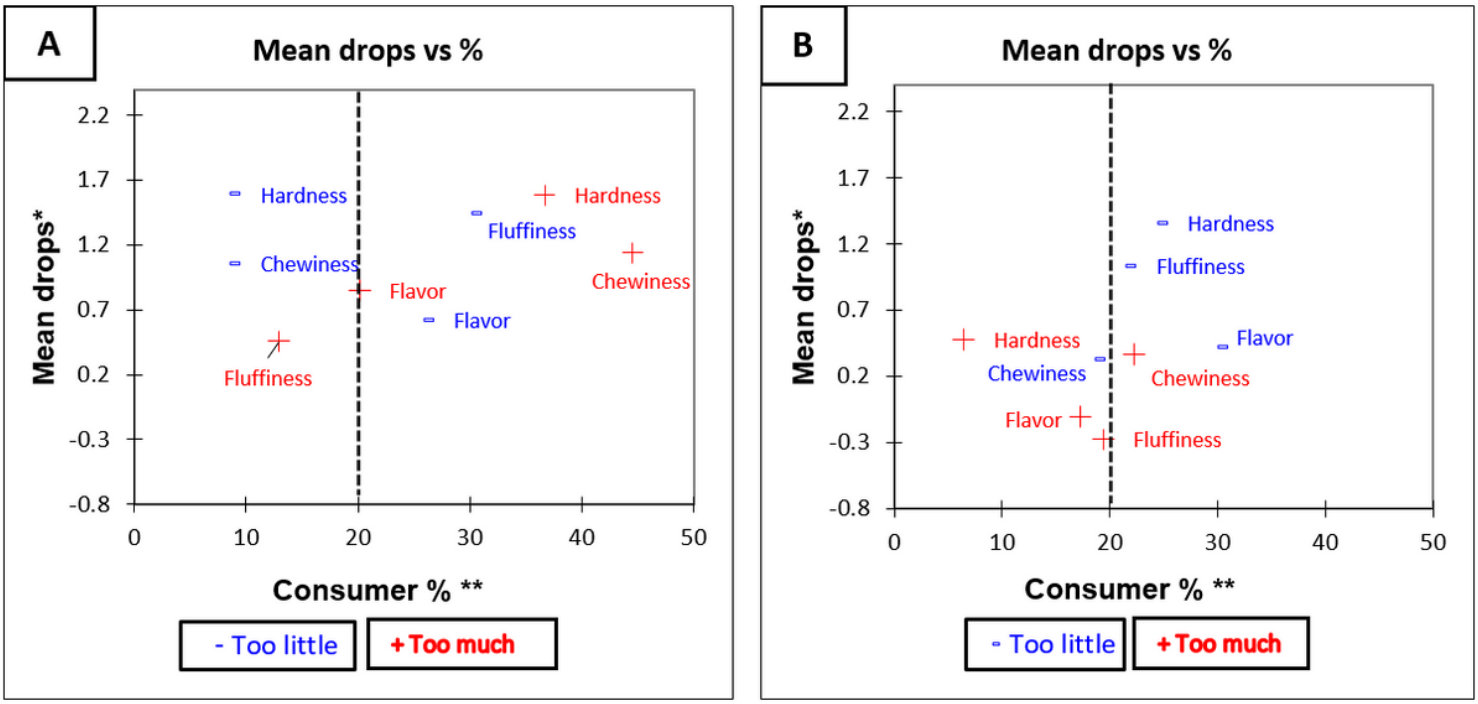

Figure 5

Mean drop plots for Jasmine rice variety after tasting A) Jasmine Brown, and B) Jasmine White * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR **Consumer % are the consumers which judged an

attribute as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrate the critical points of the product (Rothman & Parker, 2009).

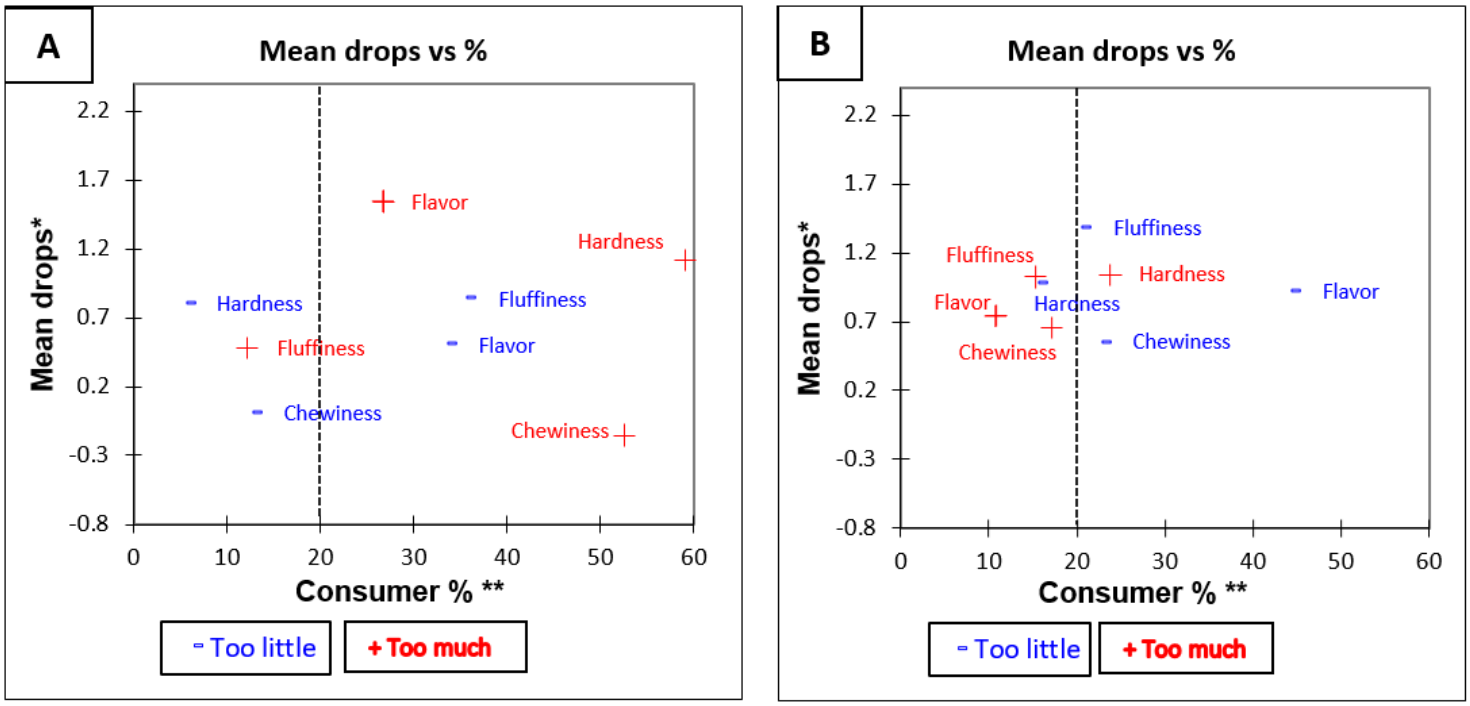

Figure 6

Mean drop plots for Low GI rice variety after tasting A) Low GI Brown, and B) Low GI White * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR **Consumer % are the consumers which judged an attribute as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrate the critical points of the product (Rothman & Parker, 2009).

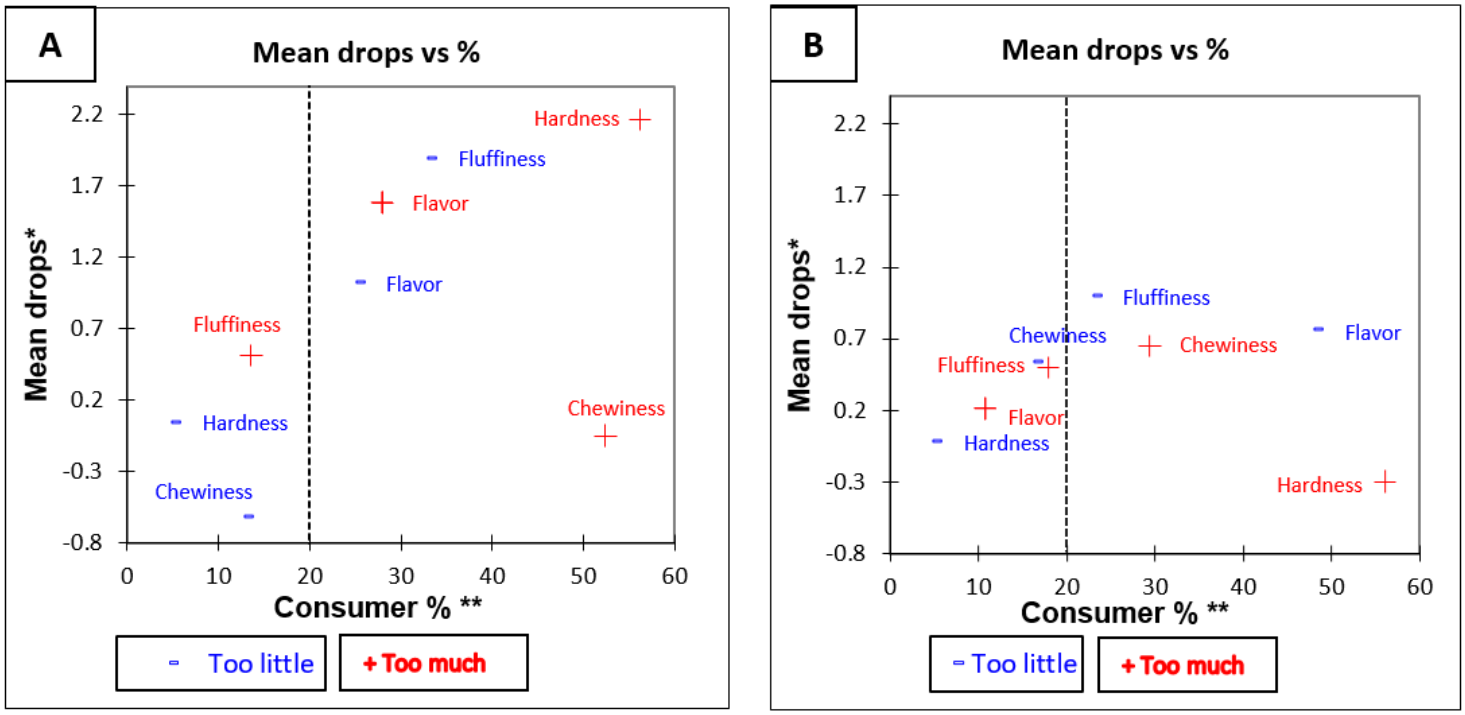

Figure 7

Mean drop plots for Med. Grain rice variety after tasting A) Med. Grain Brown, and B) Med. Grain White * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR **Consumer % are the consumers which judged an attribute as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrate the critical points of the product (Rothman & Parker, 2009).