Available online at www.sciencedirect.com

SciVerse ScienceDirect

Food Science and Human Wellness 2 (2013) 105–112

Food Science and Human Wellness

www.elsevier.com/locate/fshw

Acceptability of a reformulated grain-based food: Implications for increasing whole grain consumption

A. Manickavasagan [a,*], M. Reicks [b], V. Singh [a], A. Sawsana [a], A.M. Intisar [a], R. Lakshmy [a]

[a] Sensory and Food Preparation Laboratory, College of Agricultural and Marine Sciences, Sultan Qaboos University, Al-Khoud, P.O.Box 34, Pin 123, Oman

[b] Department of Food Science and Nutrition, College of Food, Agricultural, and Natural Resource Sciences, University of Minnesota, St. Paul, MN 55108, USA

Received 7 April 2013; received in revised form 5 June 2013; accepted 10 June 2013

Abstract

Idli is a popular Indian breakfast dish consumed by many people all over the world, made from white rice (*Oryza sativum*) (75%–80%) and black gram (*Phaseolus mungo*) (20%–25%). *Idli*'s wide consumption makes it ideal as a model for studying acceptability of a food reformulated with whole grains. The objective was to compare acceptability regarding texture, color and sensory properties when white rice was replaced with brown rice at 5 replacement levels (0% (control), 25%, 50%, 75% and 100%). Textural attributes and $L^*a^*b^*$ color values were measured by a texture analyzer and a Chroma meter, respectively. Informed and blind sensory tests were conducted. Instrumental hardness and gumminess were proportional to the level of whole grain replacement, while springiness and cohesiveness did not vary by replacement level. Liking ratings for overall acceptability were similar at the three lowest levels of brown rice replacement. Although brown rice replacement reduced the liking score for various sensory attributes, especially for 75% and 100% replacements, more than 90% of the panelists preferred brown-rice-blended *idli* as their first choice. There are ample opportunities to increase whole grain consumption through reformulation of regularly consumed traditional refined grain foods by partial or complete replacement with whole grains.

Keywords: *Idli*; Brown rice; Acceptability; Texture profile analysis (TPA); Color; Sensory test

1. Introduction

Scientific evidence suggests that the consumption of whole grain foods reduces the risk of heart disease, type 2 diabetes, obesity and certain types of cancer [1–4]. All over the world, the number of people affected by these diseases is increasing at a high rate. For example, the prevalence of diabetes in India has been projected to increase by more than 150%, from 31 million in 2000 to 79 million in 2030 [5]. Although the prevalence of obesity and overweight among adults in India is low when compared to many developed countries (1%–3%), rates of overweight and obesity among children have increased to an alarming proportion (18%–21%) [6]. The escalating levels of obesity, atherogenic dyslipidemia, subclinical inflammation, metabolic syndrome, type II diabetes, and coronary heart disease observed in India over the last 30 years are attributed to decreased intakes of coarse cereals, pulses, and fruits and vegetables, and increased intake of meat products and salts coupled with declining levels of physical activity [7]. Given the health benefits that can be realized from consumption of whole grain foods, the World Health Organization recommends increasing the consumption of whole grains [8]. However, while around 70% of total dietary calories in India are derived from carbohydrates present in plant foods such as cereals, millets and pulses [9]; these foods are typically consumed as refined grain foods. For example, in southern India, white rice consumption is generally high. A recent cross-sectional study among an urban southern Indian population showed that refined grain intake accounted for about half of total daily calories and white rice accounted for more than 75% of refined grain intake [10]. People living in many parts of this region consume white rice-based foods for their three main meals, whereas consumption of whole grains is relatively low. Results from a recent qualitative study in southern India indicated that the primary barriers to consumption of

* Corresponding author at: Sensory and Food Preparation Laboratory, College of Agricultural and Marine Sciences, Sultan Qaboos University, Al-Khoud, P.O.Box 34, Pin 123, Oman. Tel.: +968 24143646; fax: +968 24413418.

E-mail addresses: manick@squ.edu.om, manicks33@hotmail.com (A. Manickavasagan).

Peer review under responsibility of Beijing Academy of Food Sciences.

Production and hosting by Elsevier

2213-4530

http://dx.doi.org/10.1016/j.fshw.2013.06.002

brown rice were lack of knowledge of its nutritional qualities and the perception that the taste, texture and appearance were unfamiliar [11].

To increase whole grain consumption, acceptable whole grain counterparts to commonly consumed refined grain staple foods are needed [12]. Traditional, refined grain foods selected for reformulation as whole grain foods should be a staple in the diet, well liked, and have the potential to mask any unfamiliar flavors. For example, *idli* is a common, fermented breakfast food in southern India and a popular food throughout the country. It is preferred because of its spongy texture, appearance, mouth feel, taste, and aroma [13]. The major ingredients in *idli* are white rice (*Oryza sativum*) (75%–80%), and black gram (*Phaseolus mungo*) (20%–25%) [14]. Preparing *idli* involves soaking and grinding rice and black gram separately, mixing batters of rice and black gram together, fermenting the batter overnight at room temperature, and steam cooking [15]. *Idli* is a circular approximately 7–10 cm in diameter (based on mold size), and flat with a convex lower and upper surface of 2–3 cm thickness, and is tapered toward the periphery [16]. Home preparation of *idli* is convenient because the fermented batter can be stored in the refrigerator for about a week and *idli* can be cooked within a short time. In some places, this stored batter is used to prepare breakfast (*idli*) and supper (*dosa*, another traditional food made with the same batter). *Idli* and *dosa* are consumed with various chutneys, which can mask the unfamiliar flavors of a reformulated product.

Reformulation of traditional, refined grain foods to include whole grain is a novel approach to reducing refined grain and increasing whole grain intakes. Selection and acceptance of a reformulated, traditional product depends on many factors, including texture and sensory attributes [17]. The objective of this study was to determine the texture, color, and sensory properties of reformulated *idli* products, replacing white rice with brown rice. Successful reformulation of this commonly consumed, well-liked food can serve as a model for the development of other whole grain products to increase overall consumption of whole grains throughout the world.

2. Materials and methods

2.1. Sample preparation

Paddy (Ambai-63 variety) was purchased and milled in a commercial rice mill (Vijeylaxmi Modern Rice Mill, Madurai, Tamilnadu, India). White and brown rice were obtained from the same lot of paddy using different milling methods. For brown rice, milled rice was collected immediately after the removal of husk, whereas for white rice, the shelled paddy was subjected to three stages of cone polishing (100% polishing), in a continued milling process to remove the bran.

To prepare batter, 3 parts of rice and 1 part of decorticated black gram (*V*/*V*) were used. Five blends were made with white and brown rice combinations, where white rice was replaced with brown rice at 5 replacement levels (0% (control), 25%, 50%, 75% and 100%). For each combination, white and/or brown rice and black gram were soaked and ground separately, and then batters were blended and allowed to ferment at room temperature (around 22 °C) for about 10 h. A wet grinder (Premier Wonder Grinder, model 27877, 230 V AC, 50 Hz, 180 W, Sivanesan and Company, Tamilnadu, India) was used to make the rice and black gram batters. The fermented batter was poured into the round indentation pans (75 mm diameter and 20 mm thickness) in an *idli* steamer (Premier *Idli* Maker, Premier Home Appliances, India) and cooked for 15 min. Batter and *idli* preparation were replicated three times ($n = 3$).

2.2. Texture and color analysis

A texture analyzer (Model TA XT2i, Stable Micro Systems, Surrey, UK) was used to measure the force–time curve using a two-cycle compression test [18]. A plate (diameter 7.5 cm) compressed the *idli* sample placed on a mounted, fixed table. The load cell was calibrated with a 5 kg weight before experiments. The crosshead was allowed to descend at a rate of 2 mm/s to a total deformation of 30% of the thickness of the *idli* (70% compression). When the compression stroke was completed, the plunger abruptly reversed its direction and started the upward stroke at 5 mm/s. Then a second (down and up) cycle was run on the same sample. All operations were automatically controlled by the Texture Analyzer. The instrument automatically recorded the force–displacement or force–time curve. The experiment was replicated 9 times in each treatment (3 replications in each batch). Attributes determined from the force–time curve were hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness. The $L^*a^*b^*$ color values of the surface of the *idli* were measured using a Minolta Chromameter (Model CR 300, DP – 301 Data Processor, Konica Minolta Sensing Inc. UK) ($n = 9$, 3 replications in each batch).

2.3. Sensory evaluation

Untrained panelists ($n = 80$) were selected from a pool of Omani, Indian and other expatriates who were working or studying at Sultan Qaboos University in Oman. Panelists were grouped into two categories during the preliminary screening process, including regular *idli* consumers and first-time *idli* consumers. Informed and blind sensory tests were conducted for the cooked *idli* products. For the blind sensory test, no product information was provided to panelists and coded samples were given. Before the informed sensory test, panelists were given an explanation of the ingredients in the products and information about unhealthy effects of refined grains and health benefits of whole grains. Panelists were given the actual names of each sample (white rice replaced with brown rice at 5 levels: 0% (control), 25%, 50%, 75% and 100%) in the informed sensory test. Forty panelists participated in the informed and blind sensory test. Half were regular *idli* consumers (10 males and 10 females) and half were first-time *idli* consumers (10 males and 10 females).

A sensory evaluation sheet was developed, including an initial section to collect demographic information (gender, age, educational qualification and native place) and explain the hedonic sensory scale (9 – like extremely, 8 – like very much, 7 – like moderately, 6 – like slightly, 5 – neither like nor dislike, 4 – dislike slightly, 3 – dislike moderately, 2 – dislike very much, 1 – dislike extremely). In the second section, panelists were asked to test 11 attributes of the products and provide a score using the hedonic scale as reference. The attributes included appearance (color, surface texture), mouth feel and taste (softness, chewiness, graininess, moistness, oiliness), aroma (desired aroma, off-odor), and overall acceptability. At the end of the second section, panelists were asked to write their comments about the product (optional). In the last section, panelists were asked to rate the overall acceptability of the products, and to choose one product they preferred the most as their first choice.

2.4. Data analysis

The effects of brown rice replacement on each textural attribute and color were measured by a Student's *t*-test. For each texture and color attribute, the differences within treatments were tested at a 95% confidence interval (type I error, $\alpha = 0.05$) using the least significant difference (LSD) method of comparing means. The effects of sensory type, consumer type, gender, and brown rice replacement level on product quality were determined statistically. For each sensory attribute, the effects were determined by analysis of variance using four factorial design models [2 sensory types (blind vs. informed) × 2 consumer types (regular vs. first-time) × 2 genders (male vs. female) × 5 replacement-level products (0%, 25%, 50%, 75%, 100%)] with the general linear model procedure. In all analyses, differences within levels under each variable were tested at a 95% confidence interval (type I error, $\alpha = 0.05$) using the least significant difference (LSD) method of comparing means. All analyses were completed using the Statistical Analysis System software (SAS, version 8.02, SAS Institute, Inc., Cary, NC).

3. Results

3.1. Texture and color properties

The instrumental texture qualities of reformulated *idli* products are given in Fig. 1. Hardness of the *idli* products was in the range of 5–20 N, with the highest for the 100% brown rice product and lowest for the 0% brown rice product, possibly because of the presence of bran in the brown rice. There were no statistical differences in hardness between the 25%, 50%, and 75% brown rice products. No statistical differences in the adhesiveness of the 0%, 25%, 75% and 100% brown rice products were observed. However, the adhesiveness of the 50% product was significantly lower than that of the 0% product. Springiness ranged from 2.2 to 8.8 s, with no significant differences between the five *idli* products. Among the five products, no statistical differences were observed in cohesiveness or the degree to which the sample deforms (rather than ruptures) [19]. Gumminess of the *idli* products ranged from 2 to 9 N, with the 100% brown rice product having the highest and the 0% brown rice product having the lowest gumminess, and no statistical differences among the 25%, 50% and 75% brown rice products. While chewiness of the 100% brown rice product was the highest among all products, no significant differences in chewiness were observed between any products.

For many food materials, color is measured by the CIELAB system, and L^*, a^*, b^* values denote brightness (black to white), greenness-redness and blueness-yellowness, respectively [20]. The measured color values of control and reformulated *idli* are given in Fig. 2. The L^* value of reformulated and control *idli* products was between 74 and 84. The L^* value for the 0% brown rice product was the highest, while the lowest was the value for the 75% and 100% brown rice products, with significant differences between the 25% and 50% products. The a^* value for the *idli* products was in the range of 0.06–3.21. This value was the highest for the 100% brown rice product and the lowest for the 0% brown rice product, with significant differences for the 25%, 50% and 75% brown rice products. The b^* value ranged from 13.5 to 15.0 for reformulated and control products. It was the lowest for the 0% brown rice product and there were no significant differences between the 25% and 100% brown rice products.

3.2. Sensory properties

Panelists' responses for each sensory quality attribute of reformulated and control products are given in Table 1. Panelists in regular consumer group gave higher scores for all sensory attributes than the first-time consumer group.

Female panelists gave higher scores for color than males. The 0%, 25% and 50% products scored higher (without differences among them) than the 75% and 100% brown rice products. Replacing up to 50% of white rice with brown rice did not affect the color preferences of the panelists.

Gender type did not affect the scores of surface texture of *idli* products. There were no statistical differences in the surface texture of 0%, 25% and 50% products.

No statistical differences in softness scores were observed between male and female panelists. Including up to 50% brown rice in the product did not affect the softness score. There were no statistical differences in softness score between the 75% and 100% brown rice products. Gender type did not affect the chewiness preference. There were no statistical differences in liking scores for chewiness of 0%, 25% and 50% products.

Female panelists gave higher scores for graininess preference than males. The scores for graininess of the 0%, 25% and 50% brown rice products were higher (without any difference between them) than the 75% and 100% brown rice products. The addition of more than 50% brown rice might affect graininess preference due to the presence of bran particles.

Liking ratings for moistness of the 0%, 25% and 50% products (no statistical difference between them) were higher than the 75% and 100% products (with no statistical difference between them).

There were no statistical differences in liking ratings for oiliness between all five products. As the oil content of brown rice is relatively lower, it may not be sufficient to exert a significant effect on oiliness preference. However, female panelists gave higher liking scores for oiliness than their counterpart.

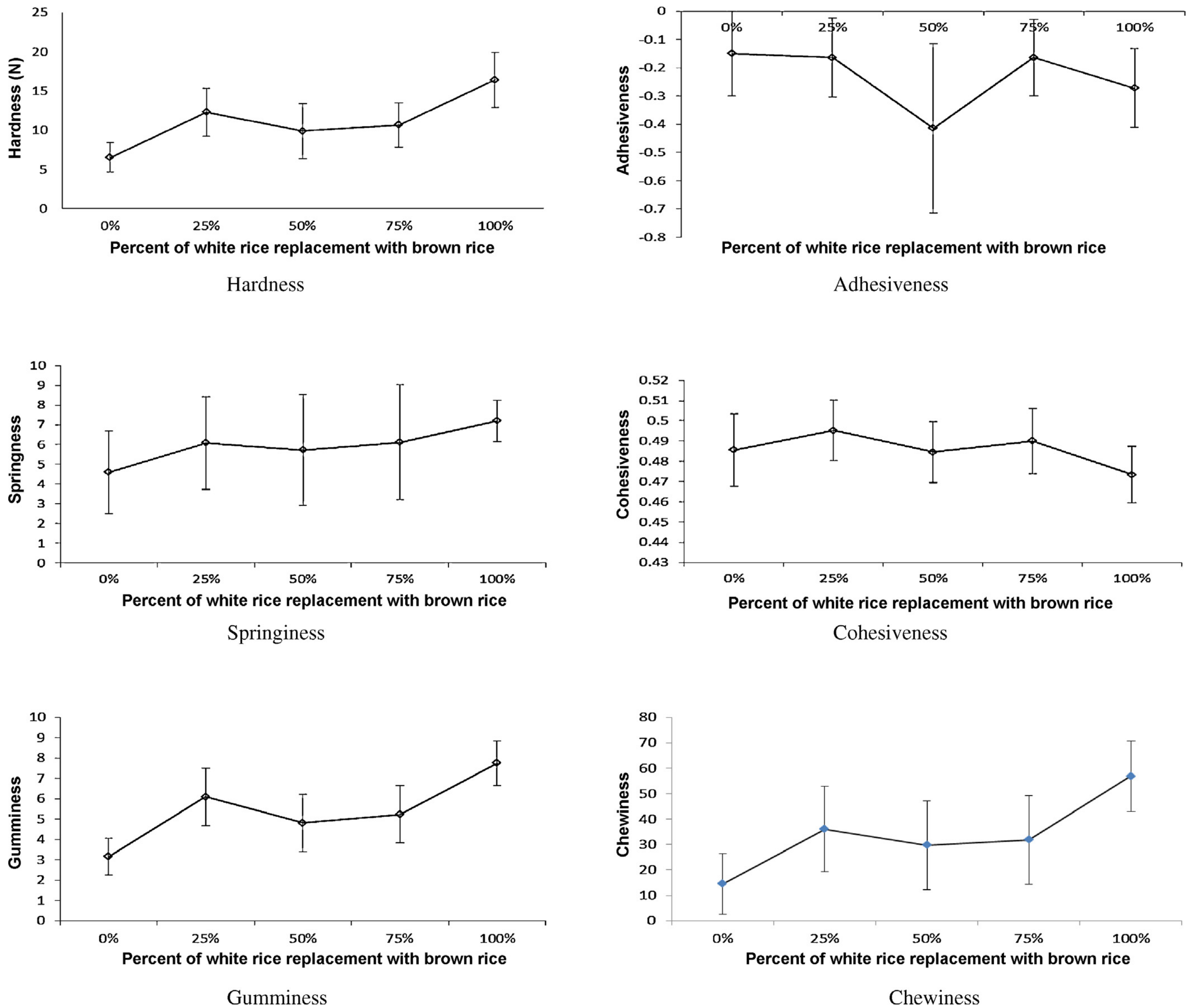

Fig. 1. Instrumental texture properties of reformulated *idli* products (mean ± SD, $n = 9$) (hardness – force to attain a given deformation; adhesiveness – force required to remove sample from a given surface; springiness – rate of return to original shape after some deformation; cohesiveness – degree to which sample deforms (rather than ruptures); guminess – being sticky and cohesive; chewiness – number of chews required to masticate before swallowing) [19].

There were no significant differences in liking scores for desired taste and off-taste between the five products and the two gender types. Therefore, the addition of brown rice may not produce any off-taste in *idli* products. The products did not differ significantly in liking ratings for aroma (both desired aroma and off-odor). Therefore, the addition of brown rice did not affect the aroma of *idli*.

In all sensory attributes, panelists in the informed sensory test gave higher scores than the blind sensory test except for oiliness and off-taste. For oiliness and off-taste attributes, there were no statistical differences in the liking scores between blind and informed sensory tests. The increase in liking of whole grain products may be explained by the increase in knowledge about their health benefits.

3.3. Overall acceptability

There were no statistical differences in the liking ratings for overall acceptability of the 0%, 25% and 50% brown rice products. However, the 75% and 100% brown rice products were given lower scores than the other products, without differences between them. The sensory test type did not affect the overall acceptability scores of *idli* products, indicating that the products were acceptable with up to 50% brown rice replacement, even without product information. Regular *idli* consumers gave higher scores for the overall acceptability of the reformulated *idli* products than their counterparts (Fig. 3). There were no statistical differences in the liking scores for the overall acceptability between male and female panelists.

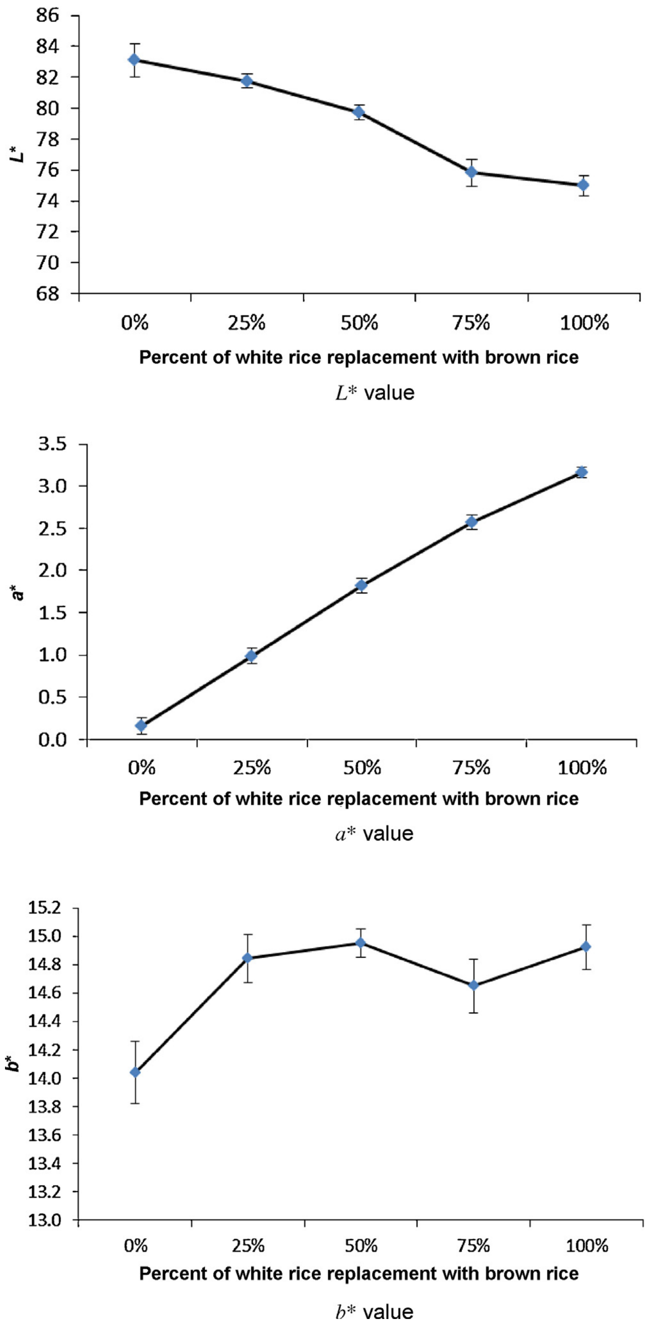

Fig. 2. $L^*a^*b^*$ color values of reformulated *idli* products (mean ± SD, $n = 9$) (L^* – brightness (black to white); a^* – greenness-redness; b^* – blueness-yellowness).

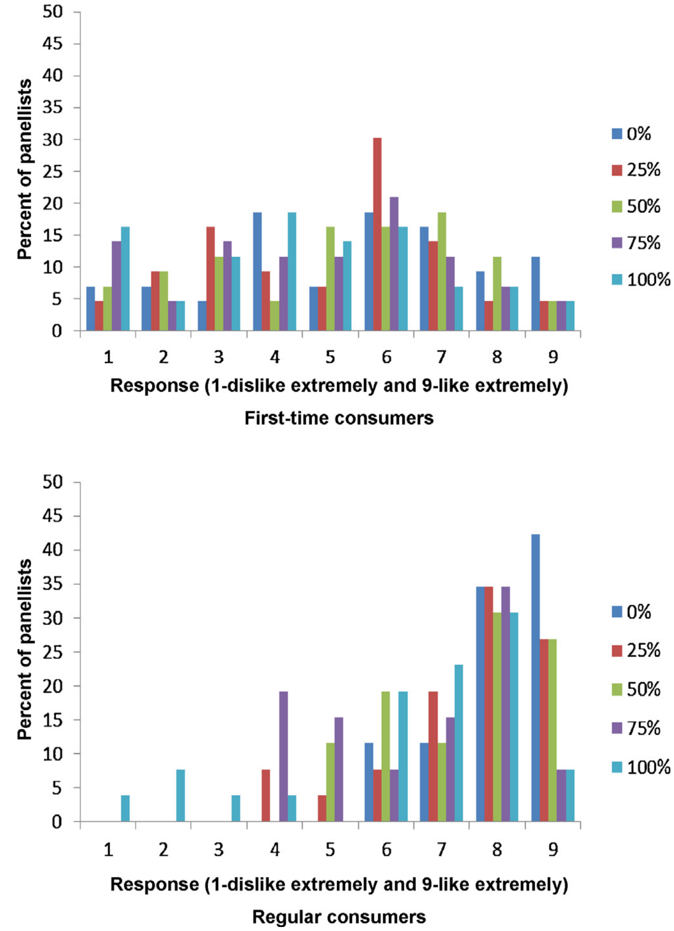

Fig. 3. Response of sensory panelists for overall acceptability of reformulated *idli* products at various levels of white rice replacement with brown rice ($n = 40$ panelists in each consumer group).

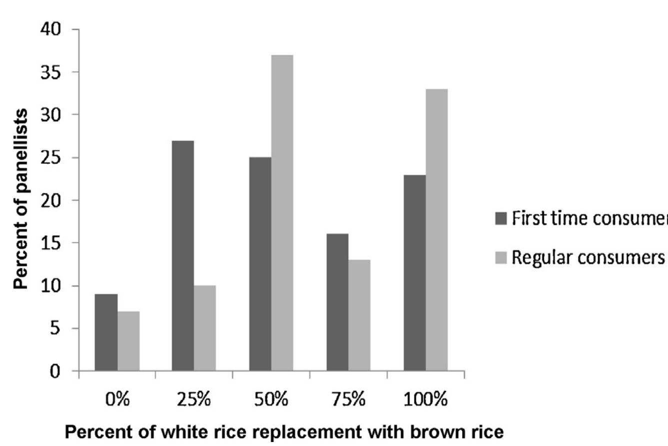

Fig. 4. First choice chosen by panelists in regular and first-time consumer groups ($n = 40$ panelists in each consumer group).

3.4. First choice

Irrespective of sensory test and *idli* consumer types, more than 90% of the panelists selected brown rice blended replacement *idli* products as the one product they preferred as their first choice (Fig. 4). Among regular *idli* consumers, around 70% of the panelists preferred 50% or 100% products as their first choice.

4. Discussion

In general, replacing up to 50% white rice with brown rice in *idli* did not affect most of the instrumental (springiness, cohesiveness, chewiness) and sensory quality ratings (color, softness, graininess, moistness, oiliness, aroma, overall acceptability).

Table 1
Mean sensory scores for various quality attributes of reformulated *idli* products at various levels of white rice replacement with brown rice ($n = 40$ panelists in each consumer group).

Sensory quality	Regular consumers					First-time consumers				
	0%	25%	50%	75%	100%	0%	25%	50%	75%	100%
Color	8.0[a] ± 1.1[b]	7.4 ± 1.5	7.1 ± 1.4	6.7 ± 1.7	6.4 ± 2.0	6.2 ± 1.9	6.4 ± 1.5	6.4 ± 1.5	6.1 ± 1.6	6.1 ± 1.6
Surface texture	7.9 ± 1.1	7.0 ± 1.6	7.0 ± 1.6	6.5 ± 2.1	6.1 ± 2.1	6.2 ± 1.8	6.1 ± 1.7	6.2 ± 1.7	5.9 ± 1.8	5.7 ± 1.8
Softness	7.8 ± 1.3	6.5 ± 2.2	6.5 ± 1.7	5.7 ± 2.2	5.7 ± 2.3	5.9 ± 2.5	5.8 ± 2.1	5.8 ± 2.2	5.5 ± 2.0	5.4 ± 2.2
Chewiness	7.5 ± 1.4	6.8 ± 1.9	6.5 ± 1.7	6.3 ± 1.9	5.8 ± 2.3	6.2 ± 2.3	5.8 ± 2.0	6.0 ± 2.0	5.6 ± 1.9	5.6 ± 2.0
Graininess	7.4 ± 1.6	6.9 ± 1.5	6.6 ± 1.6	6.3 ± 1.9	6.0 ± 2.2	6.1 ± 2.2	5.9 ± 2.1	6.0 ± 2.0	5.7 ± 2.0	5.7 ± 2.3
Moistness	7.5 ± 1.2	6.8 ± 1.9	6.8 ± 1.8	5.8 ± 2.1	6.0 ± 2.2	5.4 ± 2.3	5.4 ± 1.9	5.6 ± 2.0	5.4 ± 2.0	5.3 ± 2.3
Oiliness	7.2 ± 1.7	7.0 ± 1.6	7.1 ± 1.5	6.7 ± 1.3	6.7 ± 1.7	5.2 ± 2.7	5.3 ± 2.4	5.2 ± 2.3	5.3 ± 2.5	5.3 ± 2.5
Desired taste	7.5 ± 1.5	6.6 ± 2.1	6.7 ± 1.6	5.9 ± 2.1	6.1 ± 2.2	4.6 ± 2.3	4.3 ± 2.0	4.3 ± 2.1	4.5 ± 2.2	4.2 ± 2.1
Off-taste	7.1 ± 1.8	6.7 ± 2.0	6.7 ± 1.7	5.8 ± 2.0	5.8 ± 2.4	4.7 ± 2.2	4.4 ± 2.4	4.6 ± 2.5	4.3 ± 2.2	4.6 ± 2.3
Desired aroma	7.6 ± 1.2	7.0 ± 1.8	7.1 ± 1.4	6.2 ± 1.9	6.2 ± 2.2	5.0 ± 2.1	4.9 ± 2.0	5.2 ± 2.1	5.2 ± 1.9	4.7 ± 2.1
Off- odor	7.0 ± 1.8	6.4 ± 2.0	6.4 ± 2.0	5.9 ± 1.9	5.7 ± 2.3	5.0 ± 2.0	4.8 ± 2.1	5.1 ± 2.1	5.1 ± 2.2	4.8 ± 2.3

[a] Hedonic sensory scale rating: 9 – like extremely, 8 – like very much, 7 – like moderately, 6 – like slightly, 5 – neither like nor dislike, 4 – dislike slightly, 3 – dislike moderately, 2 – dislike very much, 1 – dislike extremely.
[b] Standard deviation.

These results are favorable with regard to increasing whole grain consumption by using *idli* or other grain products made with up to 50% whole grain ingredients.

Other studies have also shown that replacement of 50% of refined grain ingredients with whole grain ingredients did not affect acceptability, based on intake in school meals among children [21–24]. In one of these studies, children were offered pancakes and tortillas made with varying whole grain flour content [23]. Among younger children, overall liking scores were lower for whole grain products compared to refined grain products, while older children rated liking in a similar manner for whole and refined grain products. However, consumption of the whole versus refined products did not differ among younger or older children despite differences in liking ratings. Only one of these child food acceptance studies [24] also conducted an instrumental evaluation of test products made with 51% and 100% whole grain flour. Some differences were observed in texture, color, water activity, and breaking force for whole grain products when compared to control products made with refined grain ingredients.

Common barriers for consumption of whole grain products have been identified previously, and include appearance, texture, taste, cost and consumer knowledge of health benefits [25–28]. The extent to which these factors are barriers may depend on the replacement level of whole grain and consumer preference. For example, while evaluating the acceptance of bread, Bakke and Vickers [29] reported that darker color decreased the liking for subjects who preferred refined bread, but increased the liking for subjects who preferred whole wheat bread. While some participants in focus groups conducted by McMackin et al. [28] reported that taste was the most important barrier, others indicated that taste was the most influential facilitator of whole grain intake. Other barriers for some participants were also perceived as facilitators by others. Therefore, reducing the replacement level of whole grains could result in negative or positive effects on acceptance, depending on consumer preferences.

Aroma is based on the volatiles perceived by the olfactory system, with the amount of volatiles escaped from food determined by the nature of the product and the temperature. More volatiles escape from soft and porous surfaces than from hard and smooth surfaces [19]. Polishing has been shown to improve sensory rating scores for the aroma of cooked rice for two varieties commonly consumed in Asian Indian diets [30]. However, the products in the current study did not differ significantly in liking scores for aroma (both desired aroma and off-odor). Therefore, the addition of brown rice did not affect the aroma of *idli*.

Selection of new products may be based on attitudinal differences after receiving product information. Bower and Saadat [31] stated that blind sensory tests alone cannot reflect the 'real' food selection and acceptance, thus product label information must be provided in this type of study. In the current study, informed panelists gave higher liking scores for most of the sensory attributes. Therefore, creating awareness about health benefits of whole grains may change attitudes toward brown rice *idli* consumption. Results from focus group interviews among Chinese adults [32] indicated that providing information about health benefits may result in a willingness to try brown rice. Similarly, participants in focus group interviews in Southern India indicated that providing information about the health benefits of brown rice may increase consumption [11]. Creating awareness about taste may also be beneficial, as others have found that providing information about the taste of unfamiliar foods had a positive effect on selection of these foods by adults [33]. Whole grain versions of familiar foods may be unfamiliar to some because of a darker color and rougher texture. Because individuals may want to explore the taste of other traditional but less familiar foods, the acceptability of the brown rice-blended *idli* was examined by first-time versus regular consumers. As expected, the acceptance rating for the reformulated products by first-time idli consumers was lower than that for regular consumers in all categories.

Increasing whole grain consumption can be achieved in several ways. Participants in a diet modification intervention were interviewed one month post-intervention to identify behaviors that were helpful in increasing intake [12]. Replacement of refined grain foods with whole grain foods (e.g., brown rice for white rice) was noted as an important behavior. However, the current study demonstrated that it may be easier to increase intake of whole grain foods by using products reformulated to only partially substitute whole grain ingredients for refined grain ingredients, rather than 100% replacement. A previous modeling study showed that partial substitution of whole grain for refined flour in common grain foods could effectively increase whole grain consumption among U.S. children from 0.5 to 2.2 ounce equivalent per day [34]. In addition, others have recommended the substitution of white rice with brown rice, barley, couscous and quinoa in many Indian recipes as a culturally sensitive means to reduce risk of chronic disease [35]. The acceptability of *idli* reformulated with up to 50% whole grain in the current study confirms that substitution of brown for white rice is a favorable strategy that should be studied further, with respect to consumption at the consumer and household level. In many households in southern India, food is prepared at home by women who can choose the level of replacement of brown for white rice in *idli*, according to preferences of family members. Kuznesof et al. [12] reported that family taste preferences, cooking skills, price, and availability were barriers for sustained intake of whole grain foods. To reformulate *idli* to include brown rice, no additional cooking skills are required, and the product can become available as a regular traditional food. Therefore, introducing brown rice-blended *idli* into the diet of southern Indian people and ensuring sustainable consumption may be easily achieved.

Acknowledgement

This study was partially supported by the Industrial Innovation Center (IIC), Atyab Food Tech LLC and Sultan Qaboos University – College of Agricultural and Marine Sciences Dean's Seed Grant.

References

[1] A. Schatzkin, Y. Park, M.F. Leitzmann, et al., Prospective study of dietary fiber, whole grain foods, and small intestinal cancer, Gastroenterology 135 (2008) 1163–1167.

[2] J.A. Nettleton, L.M. Steffen, L.R. Loehr, et al., Incident heart failure is associated with lower whole-grain intake and greater high-fat dairy and egg intake in the Atherosclerosis Risk in Communities (ARIC) study, J. Am. Diet. Assoc. 108 (2008) 1881–1887.

[3] Q. Sun, D. Spiegelman, R.M. van Dam, et al., White rice, brown rice, and risk of type 2 diabetes in US men and women, Arch. Int. Med. 170 (2010) 961–969.

[4] M. Kristensen, S. Toubro, M.G. Jensen, et al., Whole grain compared with refined wheat decreases the percentage of body fat following a 12-week, energy-restricted dietary intervention in postmenopausal women, J. Nutr. 142 (2012) 710–716.

[5] WHO, Diabetes Program: Facts and Figures – Eastern Mediterranean Region, 2010, Available at: http://www.who.int/diabetes/facts/world_figures/en/index5.html (accessed on 01.07.11).

[6] International Association of the Study of Obesity (IASO), World Map of Obesity, 2007, Available at 222.iaso.org. (accessed 18.11.12).

[7] A. Misra, N. Singhal, B. Sivakumar, et al., Nutrition transition in India: secular trends in dietary intake and their relationship to diet-related non-communicable diseases, J. Diabetes 3 (2011) 278–292.

[8] WHO Global Strategy on Diet, Physical Activity and Health: Diet, 2011, Available at: http://www.who.int/dietphysicalactivity/diet/en/index.html (accessed on 16.10.11).

[9] National Institute of Nutrition, Dietary Guidelines for Indians – A Manual, National Institute of Nutrition, Hyderabad, AP, India, 2010.

[10] G. Radhika, R.M. van Dam, V. Sudha, et al., Refined grain consumption and the metabolic syndrome in urban Asian Indians (Chennai Urban Rural Epidemiology Study 57), Metabolism 58 (2009) 675–681.

[11] S. Kumar, R. Mohanraj, V. Sudha, et al., Perceptions about varieties of brown rice: a qualitative study from southern India, J. Am. Diet. Assoc. 111 (2011) 1517–1522.

[12] S. Kuznesof, I.A. Brownlee, C. Moore, et al., Whole heart study participant acceptance of wholegrain foods, Appetite 59 (2012) 187–193.

[13] B.K. Iyer, L. Anathanarayan, Effect of α-amylase addition on fermentation of *idli*—a popular south Indian cereal-legume-based snack food, LWT 41 (2008) 1053–1059.

[14] S. Balasubramanian, R. Viswanathan, Properties of *idli* batter during its fermentation time, J. Food Process. Pres. 31 (2007) 32–40.

[15] V.D. Nagaraju, B. Manohar, Rheology and particle size changes during *idli* fermentation, J. Food Eng. 43 (2000) 167–171.

[16] P. Nisha, L. Anathanarayan, R.S. Singhal, Effect of stabilizers on stabilization of *idli* (traditional south Indian food) batter during storage, Food Hydrocolloid. 19 (2005) 179–186.

[17] R. Shepherd, P. Sparks, Modelling food choice, in: H.J.H. Macfie, D.M.H. Thomson (Eds.), Measurement of Food Preference, Blackie Academic and Professional, London, UK, 1989.

[18] M.S. Rahman, S.A. Al-farsi, Instrumental texture profile analysis (TPA) of date flesh as a function of moisture content, J. Food Eng. 66 (2005) 505–511.

[19] M.C. Meilgard, G.V. Civille, B.T. Carr, Sensory Evaluation Techniques, CRC Press, Taylor & Francis Group, Boca Raton, FL, USA, 2007.

[20] A. Manickavasagan, G. Sathya, D.S. Jayas, et al., Wheat class identification using monochrome images, J. Cereal Sci. 47 (2008) 518–527.

[21] H.W. Chan, T. Burgess-Champoux, M. Reicks, et al., White whole wheat flour can be partially substituted for refined wheat flour red in pizza crust in school meals, J. Child Nutr. Manage. 32 (2008), Available at: http://docs.schoolnutrition.org/newsroom/jcnm/08spring/chan/index.asp

[22] R. Rosen, L. Sadeghi, N. Schroeder, et al., Gradual incorporation of whole wheat flour into bread products for elementary school children, J. Child Nutr. Manage. 32 (2008), Available at: http://www.schoolnutrition.org/Content.aspx?id=10584

[23] Y.L. Chu, C.A. Warren, P. Murano, et al., Acceptance of novel whole grain USDA commodity products by school children, J. Am. Diet. Assoc. 111 (2011) 1380–1384.

[24] A. Toma, M.B. Omary, L.F. Marquart, et al., Children's acceptance, nutritional, and instrumental evaluations of whole grain and soluble fiber enriched foods, J. Food Sci. 74 (2009) H139–H146.

[25] J. Adams, P. Griffiths, M. Reicks, The consumer and whole grains, in: L. Marquart, J. Slavin, G. Fulcher (Eds.), Whole Grains in Health and Disease, American Association of Cereal Chemist, St. Paul, MN, USA, 2002.

[26] T. Burgess-Champoux, L. Marquart, Z. Vickers, et al., Perceptions of children, parents and teachers regarding whole-grain foods, and implications for a school-based intervention, J. Nutr. Educ. Behav. 38 (2006) 230–237.

[27] L. Kantor, J. Variyam, J. Allshouse, et al., Choose a variety of grains daily, especially whole grains: a challenge for consumers, J. Nutr. 131 (2001) 473S–486S.

[28] E. McMackin, M. Dean, J.V. Woodside, et al., Whole grains and health: attitudes to whole grains against a prevailing background of increased marketing and promotion, Public Health Nutr. 4 (July) (2012) 1–9, In Press.

[29] A. Bakke, Z. Vickers, Effects of bitterness, roughness, PROP taster, and fungiform papillae density on bread acceptance, Food Qual. Prefer. 22 (2011) 317–325.

[30] S. Shobana, N.G. Malleshi, V. Sudha, et al., Nutritional and sensory profile of two Indican rice varieties with different degrees of polishing, Int. J. Food Sci. Nutr. 62 (2011) 800–810.

[31] J.A. Bower, M.A. Saadat, Consumer preference for retail fat spreads: an olive oil based product compared with market dominant brands, Food Qual. Prefer. 9 (1998) 367–376.

[32] G. Zhang, V.S. Malik, A. Pan, et al., Substituting brown rice for white rice to lower diabetes risk: a focus-group study in Chinese adults, J. Am. Diet. Assoc. 110 (2010) 1216–1221.

[33] B. Schickenberg, P. van Assema, J. Brug, et al., Information about taste stimulates choice of unfamiliar healthful food products, J. Hum. Nutr. Diet. 24 (2011) 603–611.

[34] D.R. Keast, R.A. Rosen, E.A. Arndt, et al., Dietary modeling shows that substitution of whole-grain for refined-grain ingredients of foods commonly consumed by US children and teens can increase intake of whole grains, J.Am. Diet. Assoc. 111 (2011) 1322–1328.

[35] A.A. Dixit, K.M. Azar, C.D. Gardner, et al., Incorporation of whole, ancient grains into a modern Asian Indian diet to reduce the burden of chronic disease, Nutr. Rev. 69 (2011) 479–488.