Journal of Agricultural Science; Vol. 8, No. 4; 2016
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Study on Physicochemical Properties of Rice Varieties in Fiji

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Received: January 20, 2016 Accepted: March 1, 2016 Online Published: March 15, 2016

doi:10.5539/jas.v8n4p101 URL: http://dx.doi.org/10.5539/jas.v8n4p101

Abstract

Determination of the most suitable rice varieties is to ensure the maximum sustained production for continuous economical development. In Fiji, multiple varieties of rice exist and it becomes important to identify the varieties best suited for commercial production to improve overall food security and to reduce the dependency on imports. Twenty varieties of rice cultivated in Fiji were analysed at IRRI to determine which varieties had the best characteristics for potential production. Results were correlated to determine if one variable would have an impact on another. Results indicated significant negative correlation between amylose content and the weight of milled rice (-0.715).

Keywords: rice, physical, chemical, Fiji

1. Introduction

Rice (*Oryza sativa* L.) is one of the most commonly cultivated cereal grains. It ranks as the most widely grown food grain crop and serves as the staple food for almost half of the world's population. Brown rice, which is hulled directly from rough rice, consists of a bran layer (6-7% of its total weight), embryo (2-3%) and endosperm (about 90%) (Chen et al., 1998). The most significant technological accomplishment of this century in agriculture is the development of high-yielding crop varieties. These fertilizer responsive food crops, with a high degree of resistance to insect pests and diseases, have provided on-farm yields far in excess of those obtainable from traditional varieties. They have given rise to the green revolution, which has helped many nations increase overall food production to meet the nutritional needs of an ever growing population. Ninety-two percent of the world's rice is grown and consumed in Asia, which has 55% of the world's population with the crop being a staple for provision of calories for 1.5 billion low-income people in Asia, Latin America and Africa (Walker, 1985). This is of the greatest interest in countries with large populations but with limited arable land area as the needs of a growing population can be met through development of high yielding varieties with suitable physiochemical properties. It is important to develop an understanding of the physico-chemical properties of rice which affect cooking and taste characteristics (Cheng et al., 2005). The growing demand for high yielding rice coupled with superior grain quality has become more and more urgent in rice breeding (Fitzgerald et al., 2009; Sreenivasulu et al., 2015).

Of vital importantance is to consider factors such as Amylose content to determine the suitability of rice for its use in the production of rice noodles. In Fiji, rice is the major staple food crop. The sensory qualities of rice are perhaps the most important factor in deciding the variety of rice planted by farmers. Most rice cultivation is done at a subsistence scale and hence does not impact the market as greatly as it should. However, this does impact the overall import volume as it reduces the dependency of rural residents on availability of imported rice. Moreover, hybrid varieties that are more translucent with a lower chalkiness content would be favored by farmers as these varieties have lower energy requirements for cooking (Cheng et al., 2005). This is an added bonus for farmers as most cooking locally in rural areas would be done with a supply of firewood.

Genetic and environmental factors are mainly responsible for variation in composition and cooking quality of rice (Ayres et al., 1997). For example, the variation in amylose content in rice varieties has been described by a single nucleotide polymorphism in an allele of the waxy gene encoding the granule-bound starch synthase (GBSS) enzyme by Ayres et al. (1997) and the gene is temperature-dependent (Larkin & Park, 1999). The higher environment temperature decreased amylose content in endosperm of non-waxy rice (Asaoka et al., 1985).

Chrastil (1992) showed that stickiness of cooked rice grains was related to starch-protein interactions. A relationship between amylose content and sensory values of hardness and inverse relation with stickiness of cooked rice was reported earlier (Juliano et al., 1972; Lorenz et al., 1978; Sowbhagya et al., 1987). Results have been published in which cooked rice texture has been related to protein content (Juliano et al., 1965; Onate et al., 1964).

2. Materials and Methods

A total of 20 varieties of rice kernels were used for the study which is available in germplasm nursery of Koronivia Research Station which is located at grid coordinates 18°5′46″S, 178°32′44″E on the island of Viti Levu, Fiji. A sample of 125 g was taken for analysis from the composite sample which was inclusive of the weight of husk. The samples were then wrapped in glad-wrap and packed into ziplock bags to ensure that they would be protected from weevil and rodent infestations while on transit to the test site.The sample analysis was carried out at International Rice Research Institute, Philippines. Analysis of data was done at IRRI prior to submission of the paper.

Chalkiness of the endosperm and gel consistency was calculated using milled rice. Dehulled rice was tested for protein content (percent by weight). Similarly, aroma of the rice (Fragrant compound, 2-AP (2-acetyl-pyrroline, ug g^{-1}) was measured by Gas Chromatography with a minimum detectable level of 0.125 ug g^{-1}.

3. Results and Discussion

3.1 Physical Traits (Chalkiness, Grain Length, Grain Width, Waxiness, Head Rice Yield)

Chalkiness characteristic was measured on ranges between 0-10%, 10-25%, 25-50%, 50-75% and greater than 75%. The percentages of grains with their relative results in chalkiness were obtained. Of all the varieties tested, BG75 had the lowest level of chalkiness with 1.2% of the total grain number showing chalkiness (out of which 85.6% had chalkiness between 0-10%) followed by Nandu having 1.4% of the total number of chalky grains (93% with chalkiness between 0-10%). The variety Rawele had the highest level of chalkiness with 31.4% of grains, with 20% of total grains tested having chalkiness between 0-10%, 19.2% having chalkiness between 10-25%, 54.5% having chalkiness between 25-50%, 6.3% having chalkiness between 50-75%. The cooking time for chalky varieties is greater than the cooking times for translucent varieties as described by Singh et al. (2003).

Australian Long Grain had the greatest grain length at a mean of 6.72 mm with standard deviation of 0.37 mm followed by Vietnamese long grain at 6.49 mm with standard deviation of 0.30. BG75 showed the greatest uniformity with an average grain length of 6.25 mm with standard deviation of 0.15. This meant that all grain measurements would have been more consistent in length compared to other varieties. Japani had the lowest average grain length at 5.26 mm with a standard deviation of 0.16 mm, while Vietnamese Long Grain had an average grain width of 2.05 mm with a standard deviation of 0.16 mm. Lalka Motka had the greatest mean grain width at 2.7 mm with standard deviation of 0.18 followed by Japani and Calrose at 2.6 mm each with standard deviation of 0.15 mm and 0.13 mm respectively.

Both long grain varieties of rice tested had limited grain widths. Australian Long Grain (ALG) had an average width of 1.96 mm with a standard deviation of 0.14 mm. Waxiness was only found on Vietnamese Long Grain and Ujarka Patarka. The former had a waxiness percentage of 2.8% while the latter had a waxiness percentage of 0.86%.

Correlation tests between average grain length and average grain width yielded a value of -0.60 indicating that as the value of average grain length would increase, the average width of the grain would be expected to decrease. The varieties were then tested for weight of brown rice. Results showed that a mean of 98.24 g of weight of brown rice was obtained from the 17 varieties which had data presented with a standard deviation of 1.43 g. A strong positive correlation was found between the weight of milled rice and the weight of head rice with a value of 0.83 which meant that an increase in the weight of milled rice would be due to an increase in the weight of head rice and vice versa. However, weight of head rice had an average value of 77.04 g with a standard deviation of 8.93 g exhibiting values dispersed over a wider range.

3.2 Cooking Traits (Amylose Content, Gelatinisation Temperature by Differential Scanning Calorimetry (DSC) and Consistency)

Amylose content analysis was done on a percent by weight basis. The variety ALG was found to have the lowest amylose content at 14.1% followed by Calrose with amylose content of 15.1%. The highest amylose content was found in Lakhawa at 26.6% followed by Lal Jari at 25.1% and Ujarka Motka at 25.0%. These results represented the suitability of Lakhawa for the production of any rice noodle products because higher amylose content encourages swelling (Bhattacharya et al., 1999), and these results were similar to the findings of Bao et al. (2006)

who found amylose content in the range of 7.9% to 33%. The lowest gelatinsation temperature by DSC was found in Calrose rice variety at 69.67 °C while the highest gelatinization temperature was recorded in Vietnamese Long grain at 79.92 °C followed by Australian Long Grain at 79.52 °C. Gel consistency was noted to be highest in Lakhawa at 93 and lowest in Vietnamese Long Grain at 69. Averages for amylose content, gelatinisation temperature and gel consistency were 23.02, 76.16 and 80.01 with standard deviation of 3.11, 2.00 and 7.56 respectively. There was no significant correlation observed when tests were carried out with amylose content to gelatinisation temperature having a value of 0.26, amylose content to gel consistency having a value of 0.13 and gelatinisation temperature to gel consistency having a value of 0.06. Waters et al. (2006) identified that cooking quality of rice is associated with the starch gelatinization temperature (GT). Rice genotypes with low GT have probably been selected for their cooking quality by humans during domestication.

The varieties that have been tested are sweet tasting varieties. This is why no significant amount of protein was present, which is in agreement with research conducted by Park et al. (2001) where negative correlation was recorded between sweetness of rice and overall protein content. Calingacion et al. (2014) established that rice preferences varied across regions, however, certain characters such as large translucent endosperms were consistently demanded for.

3.3 Correlation Analysis

A significant positive correlation was only seen between the values of head rice yield and the weight of milled rice with a value of 0.826 while amylose content and weight of milled rice showed negative correlation with a value of -0.715. Weak positive correlation existed between overall chalkiness and average width with a value of 0.510, and average length and standard deviation of length with a value of 0.55. Weak negative correlation was perceived between the average length and the average width and the standard deviation of length and average width with a value of -0.6 and -0.580 respectively. Weak negative correlation between head rice yield and amylose content was also found with a tested value of -0.643.

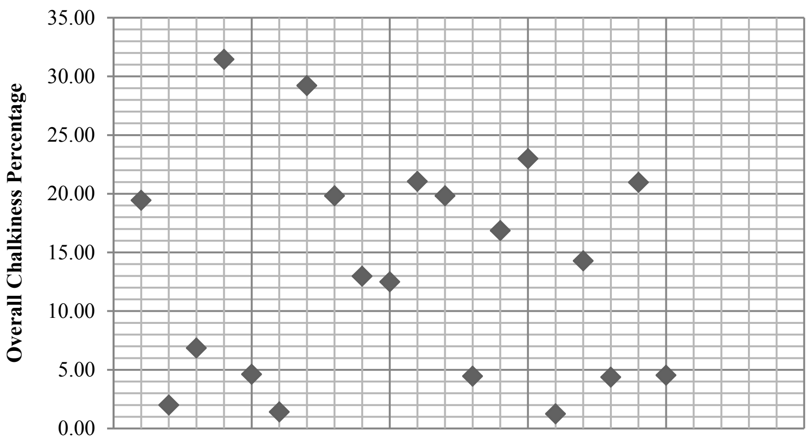

Figure 1. Scatter plot representing distribution of chalkiness percentage of the different varieties tested

Table 1. Pearson's correlation showing correlation between different variables tested

	Overall Chalkiness	Average length	Standard Deviation Length	Average Width	Standard Deviation Width	Amylose Content	Gelatinisation Temperature	Gel Consistency	Weight milled rice
Overall Chalkiness									
Average length	-0.050								
Standard Deviation Length	-0.043	0.550							
Average Width	0.510	-0.600	-0.580						
Standard Deviation Width	0.120	-0.333	0.281	-0.047					
Amylose Content	0.146	-0.346	-0.344	0.079	0.451				
Gel Temp	0.183	0.523	0.418	-0.399	0.135	0.261			
Gel Consistency	-0.025	0.173	-0.228	0.265	-0.342	0.133	0.057		
Weight milled rice	-0.112	0.437	0.312	-0.180	-0.358	-0.715	0.068	-0.274	
Weight head rice	-0.157	0.167	0.101	-0.141	-0.444	-0.643	-0.002	-0.453	0.826

4. Conclusion

All imported rice varieties showed significantly better characteristics in cooking quality and physical properties compared to the local varieties. It was noted that BG 75 was the most consistent variety in terms of translucency and grain length. The varieties with greater amounts of chalkiness should not be considered for commercial production as this negatively affects the cooking quality of the rice. This is consistent with the findings of Cheng et al. (2004). Chalkiness would increase the overall energy requirement for obtaining gelatinization and this should be considered as a factor when introducing newer rice varieties based on energy expenditure. Based on the requirements of the local niche market of Fiji, development of a local variety is critical to ensure food security and to reduce the dependency on imported rice. Identification of genes responsible for improving the overall grain quality traits would be essential to gain molecular genetic background to produce rice varieties based on consumer preference (Miura & Matsuoka, 2015).

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