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FULL PAPER

Physicochemical properties, nutritional value, and sensory quality of cassava (*Manihot esculenta* Crantz) rice-like grains

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Abstract

Cassava is one of the staple food crops grown in tropical and subtropical countries, including the Philippines. It is a cheap source of energy-dense food packed with minerals and vitamins comparable to those of many legumes. The purpose of the study was to investigate the physicochemical, nutritional, and sensory properties of cassava utilized as rice-like grains (RLGs). Four cassava varieties namely Lakan 1, Lakan 2, Rajah 4, and Binulak were utilized in the study. Results revealed that the products fall under the category of hard gel consistency. Lakan 1 had high gelatinization temperature (>74°C) while the other three gelanitized within the intermediate temperature range (70- 74°C). Lakan 1 had the highest moisture content (46.70%), Lakan 2 had the highest fat content (8.95%), whereas varieties with highest carbohydrate content are Rajah 4 (52.09%) and Binulak (52.11%). While all four varieties were similar in terms of other nutritional qualities: protein (1.18-1.32%), ash (0.35-0.81%), fiber (0.99-1.32%), Calcium (27.56-28.62%), and Zinc (0.23-0.32%). In terms of carbohydrate profile, Lakan 2 had the highest starch content (71.33%), lowest amylose (17.4%), highest amylopectin (53.93%), highest estimated glycemic index (60.49, moderate GI), and lowest total dietary fiber (4.4%). The rice-like grains made from cassava were superior to rice in terms of its higher calcium content (28 mg/100 g), lower glycemic index, greater total dietary fiber (4.4-5.4%), and longer shelf-life (11 months). Among the varieties, Rajah 4 was found to be exceptional in terms of the properties mentioned and was most liked by panelists.

1. Introduction

Cassava is said to be the crop of the poor due to its ability to provide income thereby improving the economic status of the marginalized (Hershey *et al*., 2000). Cassava plant is an efficient producer of carbohydrate in the form of starch as it is ranked as the fourth most important energy source in the human diet in the majority of the tropical regions of the world (Wheatley *et al*., 2003). Moreover, the drought-tolerant characteristic of cassava makes it able to maintain its nutritional value for long periods even without water thus presenting the potential for the future of food security in developing countries (Montagnac *et al*., 2009).

In the Philippines, cassava utilized for food is either steamed or boiled. Several products have been developed from cassava such as chips made from fresh roots, baked and puffed from flour, and dried cubes (Den *et al*., 1992). Although cassava is emerging as a fully commercial crop, rice continues to be the principal and preferred energy source in most of Asia (Hershey *et al*., 2000). The per capita rice consumption in the Philippines is increasing as rice provides most of the caloric intake most especially in the poverty-stricken areas (Francisco *et al*., 2013; Muthayya *et al*., 2014). This shows the importance of rice in ensuring food security. To date, the Philippines largely depends on rice imports from its neighboring countries in Southeast Asia to support its domestic supply.

Due to the increasing costs of rice production and importation, rice substitutes such as corn and cassava, serve as potential staple alternatives. The utilization of cassava, as rice-like grains, has not yet been fully explored despite being one the most widely grown root

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crops in the country. The purpose of the study was to evaluate the physicochemical, nutritional, safety, and sensory properties of rice-like grains made from cassava. Development of rice-like grains from cassava provides consumers with an alternative choice of staple and a potential small scale business concept, enterprising for nutrition improvement of both the urban and the rural poor. It is a potentially accessible, safe, and nutritious option for feeding during emergencies and disasters, as supplementary food, and for complementary feeding among young children.

2. Materials and methods

2.1 Materials and sample preparation

Four varieties of cassava namely Lakan 1, Lakan 2, Rajah 4, and Binulak, harvested at their 9th month of maturity, were obtained from the Institute of Plant Breeding, University of the Philippines Los Baños. These were then processed into flour. Cassava flours were made into rice-like grains by blending 100 g flour, 30 g egg, and water to make a dough. The mixture was then placed in a pasta noodle maker and cut into 1cm in length. The dough strips were steamed for 2-3 mins, then the gelatinized pellets were dried at 38°C for 4 hrs. The dried pellets were then subjected to Satake abrasive mill was then was used to shape the pellets to look like rice grains. The use of steaming and Satake mill provide a less sophisticated method, which in turn, can be easily adapted.

2.2 Physicochemical properties

Water absorption and solubility gel consistency and gelatinization were measured as described in Testing Manual for Rice (RTWG, 2000). Whereas bulk density was determined following the procedure as prescribed by Wang and Kinsella (1976).

2.3 Nutritional value

The nutritional content analyses namely: proximate composition (moisture content, crude fat, crude protein, crude ash, and nitrogen free extract), carbohydrate profile (starch, amylose and amylopectin), and total dietary fiber followed the procedures as described in AOAC (Horwitz and Latimer, 2005) while zinc was determined spectrophotometrically following the protocol of Platte and Marcy (1959). Calcium, on the other hand, was measured following the procedure as described by Guinagossian *et al.* (1977).

In vitro glycemic index was determined following the procedure and model established by Goñi *et al.* (1997) and total dietary fiber as prescribed in AOAC (2005). Starch content was analyzed according to the method prescribed by Shallenberger *et al.* (1975) while the procedure described by Williams *et al.* (1958) was followed for amylose.

2.4 Sensory evaluation

Rice-like grains were prepared for sensory evaluation by cooking the grains in a rice cooker for 9 mins at 1:1 water-RLG ratio (w/w). A total of 135 untrained adult sensory panelists participated in each cassava variety. They were asked to evaluate each rice-like grain sample in terms of its color, aroma, texture, flavor and overall liking. A 15-cm line scale was used (Lawless and Heymann, 2003) to determine the score of each attribute, anchors used are: color – white to golden yellow; Aroma – bland to strong; texture – sticky to firm; flavor – starchy to cooked rice.; and overall liking – dislike very much to like very much. A total of 15 g of boiled rice-like grains were served and presented in coded random numbers. Informed consent was solicited prior to the conduct of evaluation explaining the study objectives, extent of involvement and voluntary participation.

2.5 Stability testing

Accelerated Shelf Life Testing (ASLT) is an artificial method of determining the shelf life of the product by increasing the external stress (temperature). Three test temperatures were used during the Accelerated Shelf Life Test: 30°C, 40°C and 50°C. General acceptability in the sensory evaluation test was used as a parameter for ASLT to determine the projected shelf-life. Color analysis was also used as a basis for ASLT. This was done using a chromatometer. Actual shelf life was computed based on the factor of ten, or Q10, which is the temperature difference between the storage conditions (PhysiologyWeb, 2015).

2.6 Determination of cyanide and microbiological analysis

Cyanide content at each processing step was determined following the procedure of Cagampang and Rodriguez (1980). Finely cut sample weighing 100 mg was placed in a 16 x 150 mm tube and 0.25 mL of chloroform was added. Filter paper strips were suspended with sodium picrate. The test tubes were covered with cork stopper and allowed to stand for 12 hours. The strips were transferred to another tube to dissolve the color produced with 10 ml distilled water. The color of the sample solution was compared to the standard solutions of a known quantity of HCN. Whereas *Bacillus cereus* quantification, total heterotrophic plate count, and total yeast and mold count were determined based on the standard procedures as indicated in BAM

(2001).

2.7 Statistical analysis

All data gathered were analyzed employing Analysis of Variance (ANOVA) and Tukey's studentized range test if applicable, at 5% significance level using R version 3.5.

3. Results and discussion

Rice-like grains made from four varieties of cassava were developed. Lakan 1 or UPL Cv-2 variety has yellow flesh and a cream root cortex (del Rosario *et al.*, 2008), whereas Lakan 2 (UPL Cv-6) has a white flex and a pink cortex (UPLB, 2018). Likewise, Rajah 4 has white flesh but with a cream cortex (Mamaril *et al.*, 2007). To characterize these products, their physicochemical, nutritional, and sensory properties were determined.

3.1 Physicochemical properties

The eating quality of the developed rice-like grains as well as the physicochemical properties such as gel consistency, gelatinization temperature, water absorption index, water solubility index and bulk density were obtained. The cassava rice-like grains (CRLG) all exhibited hard gel consistency (<40 mm). Gel consistency predicts the tendency of cooked rice to harden upon cooling (Cauvain and Young, 2009). The results signify that cooked CRLGs are less sticky upon cooling and have a low degree of softness. It was noted that among the 4 varieties, Lakan 1 had the highest gelatinization temperature and the other three varieties fall under the same temperature range which is classified as intermediate. In rice, gelatinization temperature of grains is an important parameter as it determines the flexibility of rice as an ingredient. Most processors prefer an intermediate gelatinization temperature (Mutters and Thompson, 2009). Moreover, higher gelatinization temperature implies longer cooking time. One important property in preparation of starchy products is its ability to absorb and solubilize in water. Water absorption index (WAI) of the CRLGs differ in varieties, the same was observed in terms of their water solubility index (WSI). Table 1 shows that the WAI of Lakan 1 was significantly higher than the rest of the samples which is indicative of higher amylose content of the sample. Bulk density denotes the size of the grains, the CRLGs produced showed similar bulk densities and the values are close to that of short-grain rice with a bulk density of 0.579 g/mL (Brooker *et al.*,1992).

3.2 Nutritional quality

The nutrient composition of the CRLGs was characterized. It was noted that the products did not differ in their protein, ash, and fiber contents (Table 2). Whereas it was found that Lakan 2 (8.95±0.07, r<0.05) had significantly higher fat content followed by its relative, Lakan 1, while Binulak and Rajah 4 had similar fat content. Conversely, samples with the highest carbohydrate content are Rajah 4 and Binulak, followed by Lakan 2 then Lakan 1. The proximate composition is an important nutritional factor as it shows the macronutrient contents of the product. Expectedly, since cassava is composed mainly of starch, the highest macronutrient is carbohydrate. It should be noted that the samples are cooked samples, thus the high moisture content. Zinc contents (Table 2) of non-pigmented rice varieties in the Philippines ranges from 14-31 µg/g (Hurtada *et al.*, 2018), about tenfold higher than that of the samples. Cassava is said to be rich in calcium (Charles *et al.*, 2005), thus it was not surprising that the CRLGs showed notably high amounts of calcium with

Table 1. Physicochemical properties of cassava rice-like grains

Variety	Gel consistency		Gelatinization temperature	WAI (g/g)	WSI (g/100 g)	Bulk Density (g/mL)	
	Measure (mm)	Classification				Loose	Packed
Lakan 1	37	Hard	High (>74°C)	5.3	0.98	0.311	0.512
Lakan 2	34	Hard	Intermediate (70- 74°C)	0.76	0.92	0.384	0.584
Rajah 4	38	Hard		0.83	1.43	0.352	0.521
Binulak	16.67	Hard		1.68	0.122	0.348	0.529

*WAI-water absorption index; WSI-water solubility index

Table 2. Proximate and mineral composition of cooked cassava rice-like grains

Variety	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	Carbohydrate (%)	Calcium (mg/100 g)	Zinc (mg/100 g)
Lakan 1	$46.70±1.21^a$	$1.29±0.06^a$	$8.24±0.13^b$	$0.81±0.28^a$	$1.32±0.18^a$	$41.64±1.06^c$	$28.37±0.17^a$	$0.32±0.03^a$
Lakan 2	$40.77±0.29^b$	$1.26±0.10^a$	$8.95±0.07^a$	$0.52±0.17^a$	$1.15±0.27^a$	$47.34±0.70^b$	$27.56±0.11^b$	$0.25±0.03^b$
Rajah 4	$37.04±1.52^c$	$1.18±0.15^a$	$7.86±0.17^c$	$0.35±0.12^a$	$1.47±0.48^a$	$52.09±1.73^a$	$28.62±0.18^a$	$0.26±0.02^b$
Binulak	$37.21±0.46^c$	$1.32±0.27^a$	$7.90±0.10^c$	$0.47±0.21^a$	$0.99±0.23^a$	$52.11±0.46^a$	$28.36±0.09^a$	$0.23±0.01^b$

Values are expressed as mean±standard deviation (triplicates). Means bearing different superscripts in columns are significantly different. (p≤0.05). Carbohydrate is measured as nitrogen free extract by difference.

the lowest (r<0.05) at 27.56 mg/100 g (Lakan 2). The recommended daily intake of 19-29 year-old male adult is 750 mg of calcium (FNRI, 2018). This suggests that every 1 cup (approximately 200 g) of cooked CRLG satisfies 7.5% of the recommended daily intake of calcium.

Carbohydrate profile is vital parameter in rice since the ratio of amylose and amylopectin dictates the corresponding physicochemical and eating quality of rice. The CRLG samples are observed to have approximately 50% amylopectin whereas their amylose content ranges from 17 to 19%, these values fall under low amylose content with less than 20% amylose (Juliano, 1992) as seen in Table 3. The ratio of amylose and amylopectin is considered a texture determinant of rice. Higher amounts of amylose and longer chain amylopectin have a hard cooking property while a shorter chain amylopectin and lower amylose is softer (Ong and Blanshard, 1995). Low amylose rice is softer, stickier, has higher cohesion of bolus and adhesion to lips whereas hardness and roughness are higher in high-amylose rice (Suwannaporn *et al*., 2005). The estimated glycemic index is a measure of the glycemic potency of foods. It is the incremental area under the blood glucose response curve and is used to classify foods based on their blood glucose rising potential (FAO, 1997). The estimated glycemic index of the CRLGs ranged from 57.17 to 60.49, with Lakan 2 having the highest eGI and Rajah 4 the lowest. The values are lower than some of the rice varieties in the Philippines, that ranged between 68 (moderate GI) and 109 (high GI) (Frei *et al*., 2003). On the other hand, Lakan 1 had the highest total dietary fiber content and Lakan 2 had the lowest. Dietary fiber is assumed to lower the risk of cardiovascular disease, Type-2 diabetes, and colorectal cancer (Park, 2016). Dietary fiber showed several benefits such as improved intestinal function, cholesterol reduction, and increased microbial biomass (Cui and Roberts, 2009). The amount of TDF in CRLGs are significantly higher than polished rice having only 1.25% TDF (Cheng, 1993).

3.3 Sensory quality and acceptability

Sensory quality and overall acceptability of the CRLGs were determined using a 15-cm line scale results are presented in Figure 1. In terms of color, rice-like grains made from Rajah 4 was found to be more yellow compared to the other varieties, whereas Lakan 2 RLG was the whitest. Although Lakan 1 had yellow flesh, it ranked second in terms of yellowness. The yellow color observed in Rajah 4 can be related to caramelization of sugars present in the sample, this can be supported by the significantly higher nitrogen free extract of Rajah 4 CRLG than Lakan 1. Binulak RLG had the strongest aroma while Lakan 1 had the weakest aroma. In terms of flavor, all the CRLGs had no starchy flavor and had a slight resemblance to cooked rice flavor, with Rajah 4 having the highest score. Aroma and flavor of cooked rice is described as grassy, floral and sweet aromatic/ caramel (IRRI, 2006). Sweet and caramel flavor was noticeable in Rajah 4 samples. In terms of texture, the CRLGs were more on the sticky texture than firm. This may be attributed to the higher amylopectin content of cassava than that of rice. The sticky texture of CRLG differs from the major traits that distinguish rice, which is rough, slick, and most importantly, springy (Champagne *et al.*, 2010). Overall, the samples were liked by the panelists, with Rajah 4 being the most like among the CRLGs presented.

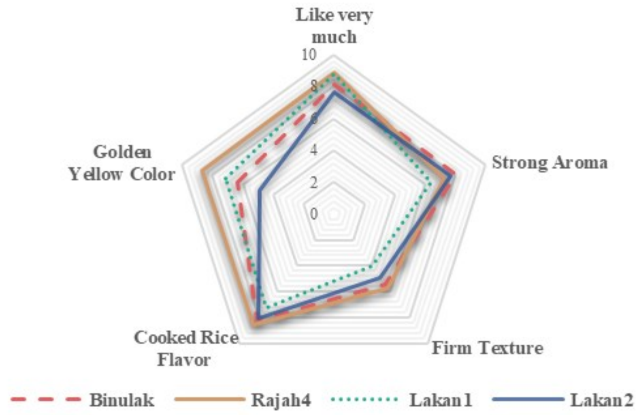

Figure 1. Sensory attributes and acceptability of the cassava rice-like grains. Color – white to golden yellow, aroma – bland to strong, texture – sticky to firm, flavor – starchy to cooked rice, overall liking – dislike very much to like very much.

3.4 Accelerated shelf-life and safety

In this study, three test temperatures were used during the Accelerated Shelf Life Test (ASLT)- 30°C, 40°C and 50°C. Laminated pouch consists of a three-ply laminate of polyester, aluminum foil and polypropylene

Table 3. Carbohydrate profile estimated glycemic index and total dietary fiber of cooked cassava rice-like grains.

Variety	Starch (%)	Amylose (%)	Amylopectin (%)	eGI	TDF (%)
Lakan 1	69.21±0.21[b]	19.43±0.59[a]	49.78±0.39[b]	59.81±0.06[b]	5.4±0.16[a]
Lakan 2	71.33±0.93[a]	17.40±0.12[b]	53.93±0.91[a]	60.49±0.09[a]	4.4±0.36[c]
Rajah 4	69.39±0.53[b]	18.69±0.27[a]	50.71±0.27[b]	57.17±0.11[d]	4.75±0.19[bc]
Binulak	67.88±0.76[b]	16.94±0.15[b]	50.94±0.78[b]	59.55±0.07[c]	5.12±0.12[ab]

Values are expressed as mean±standard deviation (triplicates). Means bearing different superscripts in columns are significantly different (p≤0.05). eGI- estimated glycemic index, TDF- total dietary fiber was selected and used as packaging material in storing CRLG samples. Microbial load-tested showed no significant change during the course of the analysis. total plate count and total yeast and molds count have yielded <10 CFU/ml, while there was no growth on the test for *Bacillus cereus*. *B. cereus* is a known pathogen that can cause food poisoning and is commonly associated with the consumption of rice. Moreover, it is a spore-forming pathogen that may survive during cooking (Lee *et al*., 2006). Thus, it is vital to test its presence in raw samples. A pH level of 6 at 50°C and 40°C was obtained, while 6.4 pH level was observed at 30°C. For ASLT method, Q_{10} was computed using the log value of the data collected from the colorimetric method (L, a, b results). The computed shelf-life (in months) of the samples is around 10 months, with Rajah 4 having the highest shelf-life of 11.73 months (Figure 2). It should be noted, however, that the packaging used is metallized laminated pouches. In comparison with rice, milled rice grains packed in LDPE had a shelf life of 4 months at room temperature (Yoon-Hee *et al*., 2005). Moreover, the sensory evaluation conducted indicated no deterioration has occurred.

Manihot species are known to contain cyanogens that during the processing of cassava, the disruption of tissues ensures that linamarase comes in contact with linamarin resulting to rapid production of free cyanide (Wheatley *et al*., 2003). Cyanide content at each processing step in the production of cassava-based rice-like grains was tested, favorably no cyanide content was found.

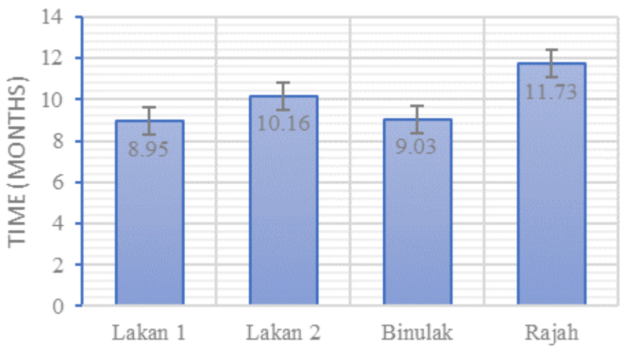

Figure 2. Predicted shelf-life (ASLT method) of cassava rice-like grain samples.

4. Conclusion

Four varieties of cassava (Lakan 1, Lakan 2, Rajah 4, and Binulak) were explored to make rice-like grains. Comparing their physicochemical properties to rice, the CRLGs are classified as low amylose with hard gel consistency. The proximate composition was fairly similar to rice except for the higher calcium content of the CRLGs. Moreover, the developed products had lower eGI than some varieties of rice. Among the four varieties, Rajah 4 was found to be superior with its high acceptability rating, cooked rice flavor, calcium content, and long predicted shelf life. The potential cassava to be used as rice analogues cannot be discounted. Further studies may be done to improve product and produce a consumer acceptable rice-like grains. Based on the results, the potential of cassava as a rice substitute cannot be discounted. Further studies may be done to make the sensory attributes of CRLGs, specifically, texture and color, more comparable to rice and to conduct consumer sensory evaluation.

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