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Research Article

Quality Characteristics of IET-13901 and Rajamudi Rice Varieties Subjected to Varying Degree of Polishing

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Abstract:

The study was planned with an objective of analyzing the various quality parameters of two rice varieties subjected to different degree of polishing, namely, 'IET-13901' and 'Rajamudi'. The samples were polished for 0, 15, 30, 45 and 60 seconds and analyzed for nutritional composition, antinutrients, starch digestibility, physico-chemical characteristics, cooking quality, and sensory attributes. Results indicated that the level of protein, fat, ash, and fiber decreased exponentially with increase in the polishing time in both rice varieties, whereas starch showed an increase. There was a decrease in phytate, tannins and oxalates as the milling levels were increased. Protein and starch digestibility were higher in well-milled rice, however, brown rice samples were better as they had a higher amount of slow digestible and resistant starch. Cooking and sensory quality of well -milled rice was better, though some attributes of lesser polished rice were also liked by panel members. The study showed that quality parameter of rice were greatly influenced by degree of polishing.

Key words: nutritional composition; antinutrients; starch digestibility; physico-chemical characteristics; cooking quality; sensory attributes

Introduction

Rice in an important cereal crop contributing as a staple to most of the South Asian population. By virtue of its proportion used in daily diet, it becomes a significant source of nutrients, though the highly polished rice being consumed now by majority is nutritionally not the best. Primary processing of paddy is essential to remove the outer husk and make the rice grain edible, however, further processing and excessive milling affect the nutritional properties adversely. Consumption of whole grain is said to be beneficial for health as any kind of processing can alter the composition of the grain (Prakash, 2013). Whole grain has many health associated components such as lignans, tocotrienols, phenolic compounds, and antinutrients including phytic acid, tannins, and enzyme inhibitors. In the process of milling or polishing, the bran is separated, resulting in the loss of dietary fiber, vitamins, minerals, phytochemicals, phenolic compounds, and phytic acid and the resultant grain has more of starch fraction (Oghbaei and Prakash, 2016; Schatzkin et al., 2007; Slavin, 2004).

Degree of milling or polishing refers to the extent of abrasion applied to remove the outer layers of grain which in turn determines the amount of nutrients retained in rice. Degree of milling has been categorized into four classes such as undermilled (3-4%), medium milled (5-6%), fully milled (7-8%), and over milled (>8%) (FAO, 1992). The distribution of nutrient across the rice grain is not uniform, hence milling causes uneven loss of nutrients making the grain richer in starch and poorer in other components (Slavin et al., 1999). In rice grain, protein, fats, vitamins and minerals are present in greater quantities in the germ and outer layers than in the starchy endosperm, which get removed on milling. Under-milled rice or brown rice, though more nutritious, has its own drawback in terms of lower storage stability on account of increased lipid peroxidation, generating rancid off-flavour. In contrast, white or highly milled rice has a very good keeping quality. White rice is also preferred by consumer due to its attractive appearance and superior organoleptic quality. Parboiled rice, on the other hand has more of nutrients because of even distribution of water soluble vitamins during hydro-thermal processing, and a much lesser degree of milling (Oghbaei and Prakash, 2010). There are many rice varieties available in different parts of the world, and new varieties are brought out with improved agricultural traits for better yield. It is essential to investigate new varieties for their quality characteristics. Hence, the present study focused on analysing a new variety of rice for various quality parameters in comparison with a traditional grown variety. Both rice samples were subjected to different degree of polishing for comparative evaluation. The quality parameters evaluated were nutritional composition, antinutrients, protein and starch digestibility, physicochemical and cooking characteristics and sensory attributes.

Methodology

Materials

For the present study, two varieties of Indian rice, namely, IET-13901, and Rajamudi were selected. They were procured from Agriculture Research Station, University of Agricultural Sciences, Bangalore, located at Mudigere of Chikmagaluru district of Karnataka State, India. The IET-13901 is high yielding paddy variety of hill zone, whereas Rajamudi is a traditionally grown variety of paddy, which was used for comparison. The grains were harvested at full maturity, cleaned, graded and stored at room temperature (25-30ºC) in airtight storage bins for aging up to 6 months. The paddy samples were then exposed to the laboratory air for 1-2 days before analytical work in order to equilibrate the moisture. The chemicals used for the study were of analytical grade. Glass double distilled water was used for all the analysis and experiments were carried out in quadruplicates.

Methods

Sample processing

The paddy samples were dehusked using laboratory scale dehusker (Rubber Roll Sheller: Model: ASR -1103). Husk and brown rice were collected separately. Further 150g of intact kernels of brown rice was subjected to different polishing time (Zero, 15, 30, 45 and 60 seconds) using laboratory scale rice polisher (Model: ASR -1104). The milled rice was sifted and separated from bran and used for further studies.

Proximate composition

The proximate principles of a food indicate the basic nutritional value in terms of major nutrients and are an indication of its physiological importance. There are major variations in the proximate composition of food depending upon the class of food it belongs, for example, cereals, legumes, or fruits, or vegetables. All rice samples were analyzed for proximate principles, and the procedures used were as follows, the moisture content was estimated following standard oven drying and repeated weighing method of AOAC (AOAC, 2000). For protein content, nitrogen was estimated by using Kjeldahl equipment (Kel plus, Pelican system, India), and the value converted using a factor of 5.95 (Ranganna, 1986). Fat was estimated by Soxhlet distillation method by repeated extraction of fat by petroleum ether, removal of solvent and weighing of residual matter. Total ash, which is an indication of mineral content of food was determined by incineration of sample in a furnace and weighing of residual inorganic material (AOAC, 2000). Dietary fiber is considered a valuable component of all foods on account of its numerous physiological functions. Insoluble and soluble dietary fiber were measured on the basis of separation of non-starch polysaccharides by enzymatic and gravimetric assay of Asp et al., (1983) which is equivalent to physiologically unavailable fiber. Total starch is the available polysaccharide which is a primary source of energy. Starch was estimated by degradation of starch to glucose with amyloglucosidase followed by determination of glucose (Batey and Ryde, 1982; Raghuramulu et al., 2003).

Antinutrients content

The antinutrients estimated in rice samples were phytates, tannins and oxalates. Phytates and oxalates bind with minerals thus decreasing their absorption from the gastro-intestinal tract. Tannins, though lower digestibility of some nutrients, are also considered beneficial on account of their antioxidant function. Phytic acid was extracted and determined according to the supernatant difference method (Thompson and Erdman, 1982). Colorimetric estimation of tannins was based on the measurement of blue color formed by the reduction of phosphotungstomolybdic acid by tannin like compounds in alkaline solution. Total tannin content was expressed as mg tannic acid equivalent per 100 g of sample (Raghuramulu et al., 1983). Total oxalates were extracted with hydrochloric acid, precipitated as calcium oxalate from the deproteinised extract and were estimated by subsequent titration with potassium permanganate (Raghuramulu et al., 1983).

In vitro digestible protein and starch

To determine *in vitro* starch digestibility, modified method of Kon et al., (1971); Holm et al., (1985) and Som et al., (1992) was followed. A 100 mg sample was digested with α-amylase, pepsin, pancreatin and amyloglucosidase sequentially with appropriate pH adjustment and incubation as required. Finally glucose was estimated in digest and converted to starch by multiplying the value by 0.9. The percent starch digestibility was calculated taking total starch into consideration.

In vitro protein digestibility was estimated according to Akeson and Stahman, (1964). A 2.0 g sample was digested with pepsin and pancreatin enzymes to follow gastric digestion, insoluble protein precipitated with trichloroacetic acid and soluble protein estimated through Kjeldahl method. The percent protein digestibility was calculated by taking total protein into consideration.

Starch profile

The starch profile is determined to establish the proportion of starch fractions which have different digestibility rates in the gastro-intestinal tract. According to the rate and extent of digestibility, starch is designated either as rapidly digestible starch (RDS), slowly digestible starch (SDS) or resistant starch. Resistant starch is not digested and is similar to dietary fiber (Englyst et al., 1992; Sergio, 2012). The starch profile of all samples was determined using the method of Englyst et al., (1992). The samples were digested with enzymes following physiological digestion procedure and the starch fractions were estimated as glucose released at different time intervals. The residual fraction was considered as resistant starch.

Physical Parameters

Physical parameters like kernel length, breadth, and linear elongation ratio were recorded as per Juliano and Parez, (1984). The alkali spreading score (ASS) of milled rice, which is an indication of gelatinization temperature was determined by the procedure suggested by (Little et al., (1958). Estimation of amylose content was done as per simplified procedure of Juliano (1971). Gel consistency was analyzed based on the method given by Cagampang et al., (1973). Cooking quality was determined by linear elongation ratio, which was the ratio of mean length of cooked rice to mean length of milled rice (Juliano and Parez, (1984).

The amylose content was estimated as per simplified colorimetric procedure of Juliano and Sukuraj (1985). In brief, a 100 mg finely ground sample, was treated with 1.0 ml of rectified spirit and 9.0 ml of 1N NaOH and heated on boiling water bath (15 min) to gelatinize the starch, transferred to a 100 ml volumetric flask and volume was made up. Five ml of this solution was drawn in a 100ml volumetric flasks, 1.0 ml of 1N acetic acid and 2.0 ml of KI reagent was then added, shaken well, volume made up and allowed to stand in dark for 20min to develop colour. Absorbance of the solution was measured in a spectrophotometer at 620nm and amylose content expressed on a dry weight basis using purified potato amylose for standard curve.

Sensory Analysis

For evaluating the sensory attributes of rice samples, rice was cooked by standard procedure and was offered to panel members with a score card. Panel members numbering 30 were semi-trained and well versed with judging the quality parameters of rice samples. The score card was designed to evaluate both the visual and eating quality of samples on a grading scale of 1-10 representing from poor to excellent quality. The visual attributes tested were whiteness of the grain, grain intactness, degree of separation and fluffiness. The edible quality included firmness, stickiness, chewiness, aroma and taste. Final overall acceptability was also scored.

Statistical Analysis

Data were computed to obtain mean and standard deviation and analyzed using analysis of variance to determine significant differences between various parameters with a statistical software SPSS 15.0 (SPSS Inc., Chicago, IL), further Duncan's multiple range test was used as post-test to determine significant difference between samples, if any (Duncan, 1995).

Results and discussion

1. Effect of degree of polishing on nutritional composition of rice varieties

Results of effect of polishing time on proximate composition of IET-13901 and Rajamudi rice varieties are presented in Table 1. As can be seen from the table, as the polishing time increased from zero to 60 sec., moisture, protein, fat, ash, insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) were found to decrease significantly whereas total starch content increased from 71.81 to 80.04%. Moisture content reduced from 12.57% in brown rice sample to 11.61% in well milled sample. This could be due to removal of the outer layers of bran that holds moisture. Protein content reduced from 6.81 to 5.65g in well milled samples. Significant decrease of 1.61 to 0.31g was observed in the fat content of IET-13901 as the polishing time increased from zero to 60 seconds. Similar trend of steep decline was observed in the total ash content, indicating the presence of most of the fat and ash contents in the outer aleuronic and bran layers of the rice kernel. This phenomenon was again substantiated by significant reduction in the dietary fiber content (both IDF and SDF).

Similar observations were made for Rajamudi rice, wherein with increase in the polishing time all the analyzed constituents except starch decreased significantly. The total starch content increased from 64.22 to 76.03%. Moisture content reduced from 12.49% in brown rice sample to 11.61% in well milled sample. Protein also decreased from 8.22 to 7.12% in highly polished rice. A significant reduction of 74.5% was observed in the fat content of Rajamudi rice polished for 60 seconds. Total ash and dietary fiber were also significantly lower in well polished rice in comparison to rice grain with zero polish and intact outer layers. Between two rice varieties, Rajamudi had higher protein and lower starch content than IET-13901.

While it is very well known that excessive polishing of rice grain decreases its nutritional quality, the data obtained demonstrate very well that the differences between brown (undermilled) and white rice (well milled) is significant. Polishing reduces the protein content by 17% in IET-13901 rice and 13.4% in Rajamudi rice. Though rice grain is not a good source of fat, the extent of reduction in fat content on polishing was 74.5 to 80.7%. Similar reduction was seen in ash content (75.6-76.4%). IDF reduced by 83% in IET-13901 rice and by 49.7% in Rajamudi rice, the extent of reduction being dissimilar in this case. SDF reduction varied from 86-90.9%. In contrast to all these, starch content was up by 11.5-18.4% showing dominance of starch in well milled rice.

The milling procedures are controlled to suit different varieties of rice after dehusking with the objective of retaining the optimum sensory quality. Highly milled rice has lesser moisture, protein, lipid, and ash contents in comparison to rice milled to a lesser degree (Juliano, 1993). This can be attributed to removal of the caryopsis coat, aleurone, and subaleurone layers, which have high ash, lipid, and fiber contents (Kim et al., 1994; Park, et al., 2001). As reported by Pedersen and Eggum (1983), highly refined rice had a lower protein content, though the amino acid composition and net protein utilization were not affected. Békés and Wrigley, (2016) studied protein and energy utilization of brown, under milled and milled rice samples of IR-32 by preschool children through diets in which 2/3 of N was from rice. They reported that brown rice was not significantly inferior to milled rice in terms of nitrogen absorption and retention by the children. Its energy and fat contents were, however, less utilized than those of milled rice. The protein quality of brown rice was reported to be higher than that of milled rice because of higher lysine content (Juliano and Bechtel, 1985). For prevention of lifestyle disorders, using whole grains such as brown rice as a staple can be significant as supported by many scientific studies (Anderson, 2003; Fardet, 2010; McKevith, 2004; Priebe et al., 2008).

2. Effect of degree of polishing on antinutrients of rice varieties

Effect of polishing time on antinutrient content of rice samples is presented in Table 2. As most of the antinutritional factors are embedded in the outer bran layers of the rice kernel, they were found to decrease exponentially as polishing time increased. The reduction observed in IET-13901 rice in phytate and tannin content were from 182 to 121mg/100g and 8.43 to 3.29mg/100g respectively which were statistically significant. Rice generally has a very low content of oxalates, which was reduced from 0.99 to 0.09mg/100g in IET-13901. Rajamudi, being red rice variety, had a higher tannin content. In this sample also, all constituents decreased concomitantly with higher degree of polishing as seen for IET-13901. The reduction observed for phytates, tannins and oxalates were from 193.75 to 121.0 mg/100g, 10.37 to 5.22 mg/100g and 0.82 to 0.12 mg/100g.When the data were analyzed in terms of percent reduction between brown and white rice, it was by 33.5% and 37.5% for IET-13901 and Rajamudi rice respectively. Tannins were reduced more in former (by 61.0%) than the latter (49.7%). Oxalates, though present in minute quantities, decreased significantly by 85.4-90.9%. Overall observation of data indicates that polishing influenced the chemical composition of rice extensively.

Apart from milling, the process of parboiling, puffing, and flaking can also cause alteration in nutrient content of rice grain. Rice can be flaked to different degree of thickness following a process of soaking paddy in hot water and roller pressing. It was reported that flaking altered the phosphorus, phytin phosphorus, and dietary fiber content of flaked rice with a decrease in proportion to thickness of flakes, the lesser the thickness, the lower was the constituent, whereas the iron and calcium contents were not affected (Suma et al., 2007).

3. Effect of degree of polishing on Starch and Protein digestibility of rice varieties

Protein and starch digestibility of rice samples is compiled in Table 3. The *in vitro* protein digestibility of both rice varieties showed an increase with enhanced milling levels. In IET-13901, it increased from 2.13 to 3.42 g/100g, whereas in Rajamudi, it increased from 2.13 to 3.42 g/100g. This is in contrast with actual protein content which decreased significantly with polishing in both rice samples. This shows that the distribution of protein in rice grain is not uniform, with outer layers having a higher proportion of protein in comparison to endosperm which has lesser amount. Between two rice varieties, Rajamudi had higher digestible protein. This also can be correlated to a higher protein content of Rajamudi rice as seen in Table 1.

Oghbaei and Prakash, (2010) studied the digestible protein in uncooked and cooked rice samples of raw and parboiled rice and reported the amount of digestible protein in the range of 6.62 to 8.10 g/100g. They also reported improved protein digestibility on cooking from 73-81% and 76 to 86.8% in raw rice and parboiled rice respectively. The increase in the protein digestibility of rice on cooking may be attributed to the inactivation of proteinase inhibitors and opening up of the protein structure through denaturation on heating. In rice flakes, the percent starch digestibility varied from 78.1 to 84.1% in flakes of different thickness (Madhu et al., 2007). Degree of flaking in rice did not influence starch digestibility significantly.

In vitro starch digestibility also increased with higher milling in both rice, the value being 24.54 to 30.22 for IET-13901 and 20.13 to 25.27 g/100g for Rajamudi. This also correlates well with initial starch content which was higher for the former and lower for the latter variety. Unlike protein, starch showed an increase both in content and digestibility with polishing. When protein and starch digestibility were computed as percent of total as depicted in Fig. 1 and Fig. 2 respectively, the observations indicated that in brown rice 31.3 to 42.9% protein was digestible and it increased to 60.5 and 73.3% on high degree of polishing. For starch differences between brown and well milled rice were smaller, the range being, 34.2 to 31.3% for brown and 37.2 and 33.2% for white rice. This indicated that polishing influenced protein content more than the starch content.

Nutritionally starch fractions are significant as they are associated with glucose release from food and determine the rate of rise of blood sugar levels. A slow and sustained release is considered beneficial in preventing common chronic diseases such as obesity and chronic diabetes (Ludwig et al., 2001). Slowly digestible starch fraction is completely digested but at a lower rate in comparison to rapidly digestible starch, whereas resistant starch functions like fiber (Englyst et al., 1992; Sergio, 2012). Resistant starch is not digested in the small intestine to produce short chain fatty acids, thus serves as substrate for growth of gut micro flora especially for lactic acid bacteria (Chung et al., 2002; Lee et al., 2010). Thereby it is shown to have various therapeutic health benefits such as prevention of colon cancer and hyperglycemia.

Effect of polishing time on starch profile of rice variety IET13901 presented in Table 3 shows that RDS content increased as the polishing time increased from 57.94 to 76.83%. On the other hand, SDS and RS content of rice samples decreased significantly from 8.63 to 2.11% and 5.24 to 1.11% respectively on polishing. This indicated that increased polishing time associated with increased abrasive milling and consequent removal of bran and aleuronic layers adhered to endosperm decreased SDS and RS content significantly. Similar trend was seen for Rajamudi rice, wherein RDS content increased significantly from 52.22 to 72.62%. SDS and RS content reduced from 8.13 and 3.87% in brown rice samples to 2.14 and 1.27% in well milled samples respectively (Table 3). It has been reported that in pre-processed expanded rice products such as puffed rice, popped rice, and rice flakes, the starch digestibility was higher than raw milled rice. Parboiled rice also exhibits higher starch digestibility than raw rice, however, it was lower than ready-to-eat expanded products (Chitra et at., 2010). Kamaraddi and Prakash (2015) studied the effect of varietal differences of rice on nutritional characteristics of expanded rice and reported a range of 69.7–76.2% of protein digestibility and 80.3–82.8% of starch digestibility.

4. Effect of degree of polishing on physicochemical and cooking characteristics of rice varieties

The data on physico chemical and cooking characteristics of rice varieties is compiled in Table 4. Disruption of bran layer with increase in degree of milling resulted in more water uptake on cooking with increased kernel elongation ratio (KER) from 1.15 to 1.96 and volume elongation ratio (VER) from 2.23 to 4.072 in IET-13901. A slight increase in percent loss of solids with increase in the polishing degree was witnessed from 5.31 to 5.64% as a result of leaching out of starch from grains and brokens. Amylose content increased from 25.21 to 28.40% with resultant increase in alkali degradation score (ADS) and gel consistency values from 3.75 to 5.40 and 33.75 to 48.18 mm in brown rice and well milled samples of IET-13901. Comparative values for Rajamudi rice demonstrated a slightly lower extent of KER with a maximum of 1.41, and a higher VER at 4.32. This could be attributed to their grain size and shape. Gruel loss was almost in similar range to IET-13901. The amylose content showed a marginal increase from 25.28 to 26.78% In Rajamudi. An amylose content of 25-33% is said to be high and based on this both varieties could be classified as high amylose rice (Juliano, 1971; Juliano and Bechtel, 1985). Amylose content is important as it is the key determinant of the cooking and processing qualities of rice (Bhattacharya, 2011). Varieties with high amylose are dry and flaky and are suitable for making canned and quick cooking rice. The alkali degradation score of Rajamudi rice also increased significantly on polishing. The differences in gel consistency on polishing were similar in both varieties. Based on gel consistency values, the unpolished grain, and the grain milled for 15 seconds could be classed as ‘hard’, and the rest could be classed as ‘medium’ (Cagampang et al., 1973). Rajamudi is basically a brown rice variety eaten in a lesser polished state, hence, it is said to be more nutritious. Rice with higher degree of polishing carry better cooking quality because of textural changes which is due to the removal of dietary fiber and reduction of protein contents (Park et al., 2001).

5. Effect of degree of polishing on sensory attributes of cooked rice varieties

The results of sensory analysis of cooked samples of both rice are presented in Table 5. As the polishing time increased, whiteness of the IE-13901 rice kernel increased from 4.90 to 9.25 due to removal of bran, least score (4.90) being given to brown rice samples, and the highest was for well milled samples. At 30 seconds of polishing time, rice sample had the whiteness score of 7.58 which differed significantly from ‘reasonably well-milled’ and ‘well-milled’ samples respectively. Fluffiness was found to increase significantly due to increased absorption of water. Firmness was also found to increase significantly as the polishing time increased. Degree of separation was more in brown samples with lowest stickiness scores. As stickiness increased, the degree of separation decreased. Chewiness was more in lesser milled samples, and reduced thereon significantly (from 4.72 to 2.67), contributing to the palatability of rice. Aroma and taste were also given higher scores for well milled samples, however, differences between samples were smaller. Overall acceptability scores of the cooked rice sample of IET-13901 showed that 45 seconds of polishing resulted in highest acceptability followed by rice milled for 30 seconds indicating that over milling may not improve the sensory characteristics, and rice with partial polish could be favored by consumers.

Rajamudi is a preferred red rice variety, valued for its characteristic taste and flavor. Even though it has reduced head rice recovery upon milling, it is preferred by the traditional rice consumers. The sensory scores of cooked rice samples milled at different polishing time were found to vary significantly when evaluated by semi-trained panel. Whiteness increased from 4.47 to 8.08 with >80% reduction in red color. Grain intactness improved with increase in the time. Degree of separation decreased and was found to differ significantly. Increase in fluffiness was observed from 6.50 to 8.47. Firmness increased up to 4-5% of polishing as Rajamudi has more percentage of stress cracks; cooked rice was stickier due to increased stickiness score as polishing time increased, chewiness values significantly reduced from 3.82 to 2.75 and the rice was found to be highly palatable. Aroma increased initially, lightly milled samples scored highest for characteristic aroma (9.02) and found to decrease significantly with increase in polishing time. Branny taste (still preferred) reduced with increase in polishing time. Brown rice as well as under milled rice samples of Rajamudi and IET-3901 variety were acceptable by the semi trained panel members with slightly more score for lightly milled samples. Polishing significantly improved the grain intactness and fluffiness of both rice varieties by 30 to 60%. Chewiness reduced significantly by around 32-40% in Rajamudi and IET-3901. Polishing significantly improved the aroma and taste in both rice types. Overall results of sensory analysis shows that rice with partial polish could be accepted by consumers, and flavor of brown rice was also accepted.

Conclusion

The results of the study indicate that all analyzed quality parameters of rice were greatly influenced by level of polishing. As the level of polishing increased, there was a decrease in protein, fat, ash, and dietary fiber content and an increase in starch content. Antinutrients also showed a concomitant decrease with polishing levels. *In vitro* digestible protein and starch were higher in well-milled rice, though brown rice (with lesser polish) had a higher proportion of SDS and RDS. Well-milled rice had better cooking quality. Sensory analysis indicated mixed response where both brown and white rice were accepted for certain attributes. In conclusion, it can be said that degree of polishing significantly influenced all quality parameters of rice and from health point of view, partial polish can be recommended to retain the health benefits organoleptic quality of rice.

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