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Effect on Physio-Chemical, Textural and Nutritional qualities of Pressure parboiled *karuppukavuni rice (Oryza sativa* L. *indica)*

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ABSTRACT: White rice is typically replaced with non-glutinous *karuppukavuni* rice variants as a staple diet. Consumer interest in the new processed goods made with *karuppukavuni* rice is developing quickly. The effect of pressure parboiling of *karuppukavuni* (*Oryza sativa* L. *indica*) rice on the physical, chemical, cooking, textural and nutritional characteristics with the varying process parameters were investigated. The pressure parboiled *karuppukavuni* rice was compared with the raw *karuppukavuni* rice, among the different experimental combinations of pressure parboiling condition with the cold soaking for 4 hours, pressure under 1.5kg/cm^2 for 30 minutes was observed the suitable pressure parboiling method with minimal physiochemical changes in *karuppukavuni*. The treatment resulted in increase in head rice yield (70.50±1.67 to 88.84±0.23), with the minimal colour (3.07±0.01) change. The cooking time of pressure parboiled *karuppukavuni* rice was increased (76.37±1.98 to 90.28±1.18). Pressure parboiled *karuppukavuni* rice resulted in increased hardness (216.1±58.8 to 514.0±15.1) and increase of protein (9.19±0.0 to 11.23±0.24), carbohydrate (69.72±1.20 to 71.67±1.91) and ash (1.88±0.2 to 2.78±0.15), leaching of crude fat (5.89±1.28 to 3.68±1.01) and crude fiber (1.04±0.01 to 0.90±0.0).

Keywords: *Karuppukavuni (Oryza sativa* L. *indica),* pressure parboiling, anti-oxidant, physiochemical.

INTRODUCTION

One of the most extensively used grains in the world is rice (*Oryza sativa*). Rice is a staple crop in many Asian countries and in India. Rice is the primary source of food consumed by people. Rice is considered to be a rich source of dietary fiber, riboflavin, thiamin, magnesium, phosphorus, niacin and source of energy. Based on the color, rice is categorized into white, black, red, green varieties. The color of the rice is determined by anthocyanin pigment composition. Anthocyanin are water soluble pigment, flavonoids, glycosylated polyphenolic compound (Tanaka & Ohmiya 2008). Anthocyanin act as antioxidant, fighting free radical, and in addition to that they are having benefits of anti-cancer, anti-viral and anti-inflammatory. Because rice is a primary food for the majority of the world's population, producing therapeutic rice types with increased nutritional value will have a bigger influence on preventing the aforementioned lifestyle problems. This paved the way to traditional rice varieties. Traditional colored rice variants are high in resistant starch, dietary fiber, flavonoids, minerals, polyphenols, and carotenoids and eating grains from pigmented rice varieties can assist improve human health. It is anticipated that the dietary supplementation of these ancient rice variants' bioactive phytochemicals and micronutrient constituents will be crucial in lowering the prevalence of non-communicable diseases like cardiovascular disease, diabetes, cancer, and stroke (Vichapong *et al.,* 2010). To minimize the usage of white rice and switch to unpolished or coloured rice, numerous programmes have been put into place (Helmyati & Wigati 2022). As a result, black rice seems to have become a popular alternative to white rice (Noorlaila *et al.,* 2018) The *Karuppukavuni* rice grains were black in colour and were high in minerals including copper, zinc, potassium, sodium, and manganese. It has a lower total sugar content, a lower fat content, a higher protein content, and higher quantities of carotenoids, phenolic acids, and flavonoids (Raj & Sankaran 2021). It was found to have anti effects in addition to its nutritional value because of its innate ability to regulate blood sugar levels (Reddy, 2018). The digestible fiber is found to be least content and resistant starch is in higher amount in *karuppukavuni* rice (Haldipur & Srividya 2020).

Pressure parboiling resulted to reductions in whiteness, improvements in hardness, transparency, and equilibrium moisture content. Parboiled rice had a higher degree of gelatinization than the other treated samples. A lower GI was associated with rice that contained more amylose and parboiled rice had such a significantly lower GI (Sivakamasundari *et al.,* 2020). Study conducted by (RAJ & Singaravadivel 1982), it is resulted that due to parboiling the paddy, the free fatty acid (FFA) level of the bran dropped. Pressure parboiling significantly lowered the FFA compared to the other parboiling techniques.

MATERIALS AND METHODS

A. Sample

A sample of *Karuppu Kavuni (Oryza sativa* L. *indica)* paddy was obtained from Thiruvarur District. The obtained paddy's initial average moisture content was 12%. It was stored at ambient condition (Temperature 15 – 25 °C) until required for experiment.

B. Experiment Design

Ten experimental runs were carried out by using 4 independent variables: soaking methods, soaking time, steaming pressure, steaming time combinations was explained in Table 1.

Pressure Parboiling process of *Karuppukavuni* Paddy. Pressure parboiled *karuppukavuni* paddy processing consists of the process of soaking (Hot and cold), autoclave under pressure (1.5 kg/cm²), and drying (sun). The parboiling of paddy was done in two separate ways as hot soaking (65°C) and cold-soaking (room temperature- 27 to 30°C). The paddy was cleaned and soaked in water with varied temperature (65°C & room temperature) and soaking time (30 – 120 mins). The water was drained from the paddy, which then kept in the vessel for steam in an autoclave at a pressure explained as in the experimental design (Table 1). After steaming, the grains were removed and spread out on a tray to dry, bringing the moisture level down to 13–14% (w.b.).

Moisture Content of paddy. The amount of moisture in the grain and the temperature at which it is dried are both important factors in determining whether minor fissures and/or full splits are introduced into the grain structure. The paddy moisture content was evaluated by drying 5 g of the sample for 24 hours at 105 ± 5 ° C in a hot air oven. The value of percent wet basis (% wb) was calculated using the formula

$$\text{Moisture content of paddy \%} = \frac{\text{Initial weight of the sample (g)} - \text{Final weight of the sample (g)}}{\text{Initial weight of the sample (g)}} \times 100$$

Table 1: Experimental design on *KaruppuKavuni* Paddy.

Sr. No.	Sample ID	Treatment			
		Soaking methods	**Soaking Time (hrs)**	**Steaming Pressure (kg/cm²)**	**Steaming Time (min)**
1	Control	-	-	-	-
2	PP1	Hot soaking	2	1.5	30
3	PP2	Hot soaking	3	1.5	30
4	PP3	Hot soaking	4	1.5	30
5	PP4	Cold soaking	0.5	1	60
6	PP5	Cold soaking	0.5	1.5	120
7	PP6	Cold soaking	1	1.5	60
8	PP7	Cold soaking	1	1.5	120
9	PP8	Cold soaking	2	1.5	60
10	PP9	Cold soaking	2	1.5	120
11	PP10	Cold soaking	4	1.5	30

Control – Raw, PP – Pressure parboiled.

Milling of Paddy. The main objective of a rice mill is to separate the outer surface of husk and bran, leaving behind an edible, well processed, and contaminant-free rice kernel. Using a Satake rubber roll sheller, control (unparboiled paddy) and parboiled paddy samples among all treatments were dehusked in two passes, producing brown rice.

C. Physical properties of rice

Head rice recovery. The weight proportion of entire rice (three-fourths kernel or greater) after through milling is known as head rice yield. The formula was used to determine the percentage of head rice recovered

Head rice recovery = $\frac{W_{Hr}}{W}$ x 100

Where, W_{Hr}= weight of head rice (g)

W = weight of paddy (g)

Broken rice percentage. A sample was taken at random in triplicate to determine the broken percentage. Broken grains were defined as those that were shorter than 3/4th of the grain length and were separated by manual picking. Broken percentage were calculated by the formula referred by (Alizadeh, 2011).

Broken rice percentage = $\frac{W_{Tbb}}{W_{Bbb}}$ x 100

Where, W_{Tbr}= Total brown rice weight (g)

W_{Bbr}= Broken brown rice weight (g)

Thousand grain weight. The weight of each thousand grain was calculated by carefully counting and weighing each grain on a digital scale. Three replications' average was calculated (Gujral et al., 2002).

Colour changes. *ColorFlex EZ* Hunter Lab Chroma meter was used to determine the colour of the sample. The outcomes are represented by the letters L, a, and b.(Kumar & Prasad, 2018)

Cooking properties of rice. In accordance with the method described by (Chavan et al., 2017), the cooking properties such as cooking time, cooking coefficient, water uptake ratio, gruel solid loss, length-breadth ratio, were evaluated for raw and parboiled rice using the following equations,

Water uptake ratio (%) =

$$\frac{\text{Cooked rice weight in grams} - \text{Raw rice weight in grams}}{\text{Raw rice weight in grams}} \times 100$$

$$\text{Cooking coefficient} = \frac{L_{ac} - L_{bc}}{B_{ac} - B_{bc}}$$

Where

L_{ac} = Length after cooking (mm)

L_{bc}= Length before cooking (mm)

B_{ac} = Breadth after cooking (mm)

B_{bc}= Breadth before cooking (mm)

$$\text{Gruel solid loss (\%)} = \frac{\text{Increase in weight of dish}}{\text{rice sample weight}} \times 100$$

Texture profile analysis. The texture of the cooked rice before and after pressure parboiling process was determined using Texture Analyzer (Stable Micro Systems TA.HD plus C Texture Analyzer (Godalming, United Kingdom). The platform contained a single number of cooked rice. A special test program was selected, the probe used in the equipment for the analysis were Probe P/5 and it was used with pretest speed – 1.00 mm/s, test speed – 0.5 mm/s, posttest speed – 1 mm/s, target mode type – distance – 2mm, time – 5 sec. Compression was to 100% strain. Parameters acquired from test curves were hardness, cohesiveness, adhesiveness, springiness, gumminess, chewiness (Park *et al.,* 2001).

Nutritional Qualities. The moisture, ash, protein, fat and fiber content of raw and pressure parboiled sample were determined by official methods 945.38, 941.12, 979.09, 945.38 and 920.86 (AOAC, 2016). The carbohydrate percent was determined by subtracting from 100 the moisture, crude fat, crude fibre, crude protein, and ash values acquired from different treatments (Abdul-Hamid *et al*., 2007).

D. Statistical analysis

Every test was run in triplicate. The general linear model (ANOVA) and Tukey's multiple comparison test were used by Minitab Statistical Software to assess the statistical differences.

RESULTS AND DISCUSSION

A. Changes in Physical properties of raw and pressure parboiled Karuppukavuni rice

Head rice recovery. The milling quality of rough rice improved significantly after parboiling treatment. The parboiling process provides the grains toughness, which helps them resist breaking during milling, reducing breakage and increases milling yield (ISLAM *et al.,* 2002). The maximum head rice recovery of 99.8% was obtained on the pressure parboiling treatment three when the soaking type, soaking time, steaming time and steaming pressure were hot soaking, 4 hours, 30 min and 1.5 kg/cm^2 respectively, and the minimum head rice recovery was attained on the fourth pressure parboiling treatment when these factors were cold soaking, 0.5 hours, 60 min and 1 kg/cm^2 respectively, resulting of 71% whereas the pressure parboiling treatment ten (PP10) poses the factors of cold soaking type, 4 hours soaking time, 30 min steaming time and 1.5 kg/cm^2 steaming pressure which provides overall satisfactory results has the recovery of 88.84% and the recovery of control (un-parboiled) sample were 70.5% as indicated in (Table 2). The head rice recovery percentage showed significant difference ($p<0.05$) between control and treated samples. They increase with increase in soaking temperature and soaking time and decrease with decrease in steaming pressure and combination of soaking time and steaming time respectively. Head rice recovery of parboiled rice is higher because pre-gelatinization mends grain fractures and parboiling hardens the grains and increases their resistance to breaking during milling. Because the rice kernel absorbs water while soaking, starch granules swell (Hapsari *et al.*, 2016). Soaking at room temperature slows, whereas the hot soaking achieved better removal of outer layer without damaging the rice kernel.

Broken Percentage. In contrast to head rice yield, it showed a reversal pattern for broken rice, with high head rice recovery in the sample leading to low broken percentage (Chavan *et al*., 2017). The observed broken percentage showed a significant difference ($p<0.05$) for sample was given in (Table 2). For un-parboiled sample, it was 29.63% whereas for pressure parboiled sample heading from 0.19% for treatment three it increased up to 29.01% for treatment four. The broken percentage for treatment which gives overall satisfactory result was 11.37%. Starch gelatinization and protein denaturation boost the breaking strength of parboiled rice, possibly filling the vacuum gaps in the kernels and reducing cracks. Lower degree of starch gelatinization, on the other hand, has a negative impact on this physical quality, increasing the chances of damaged grains. The breaking resistance of parboiled rice is significantly affected by the heating parameters during the steaming process, with extreme heating causing a 100 percent increase in DSG, boosting the head rice yield. On either side, during the parboiling process, due to the moisture content disparities inside the grains, cracks may form during the soaking step, contributing to rupture. Furthermore, kernels that are much more prone to breakage, such as core grains, may form during the parboiling process as a result of gelatinization of the outer surface under conditions where there is no moisture equilibration and, as a result, the moisture in the center of the kernel is insufficient to ensure adequate starch gelatinization (Villanova *et al.,* 2020).

Thousand grain weight. The net weight of 1000 rice kernels in grams was used to calculate the weight of a thousand grains (Table 2). The thousand grain weight was observer to be decreased on pressure parboiling conditions from 23.78 gm for raw rice to on varies treatments decreased from 23.67±0.43gm to 22.90±0.29gm for the treatments of five and six respectively. The Thousand grain weight for treatment which gives overall satisfactory result pressure parboiling treatment ten (PP10) was 23.00 gm. Milling and shelling are the main cause for the loss of a third of the paddy, as the former procedure removes the bran and husk covering from the paddy (Kumar & Prasad 2018). The leaching process also contributed to the weight loss in parboiled samples when compared to controls (Jayaraman *et al.,* 2019).

Table 2: Effect of physical properties on raw and pressure parboiling of *Karuppukavuni* rice.

Sr. No.	Sample I.D	Head rice recovery (%)	Broken percentage (%)	Thousand grain weight (g)
1.	Control	70.50±1.67^{d}	29.63±1.72^{a}	23.78±0.53^{a}
2.	PP1	99.29±0.04^{a}	0.73±0.06^{de}	23.08±0.04^{bc}
3.	PP2	99.56±0.23^{a}	0.68±0.15^{de}	23.23±0.08^{abc}
4.	PP3	99.80±0.03^{a}	0.19±0.03^{e}	23.06±0.09^{bc}
5.	PP4	71.00±1.46^{d}	29.01±1.43^{a}	23.46±0.11^{abc}
6.	PP5	93.70±0.29^{b}	6.45±0.21^{c}	23.67±0.43^{ab}
7.	PP6	90.73±0.93^{c}	9.46±0.95^{b}	22.90±0.29^{c}
8.	PP7	97.74±0.06^{a}	2.47±0.06^{d}	23.54±0.03^{abc}
9.	PP8	98.98±0.32^{a}	1.10±0.38^{de}	23.37±0.15^{abc}
10.	PP9	98.04±0.50^{a}	2.01±0.48^{de}	23.39±0.09^{abc}
11.	PP10	88.84±0.23^{c}	11.37±0.23^{b}	23.00±0.06^{bc}

Control – Raw, PP – Pressure parboiled

A statistically significant difference ($p<0.05$) between the control and different treatments is indicated by different lowercase alphabets in the same column superscript.

B. Changes in colour attribute of raw and pressure parboiling of Karuppukavuni rice

Hunter L-values are a measure of how light or bright a rice sample is shown in (Table 3). The L-values for the pressure parboiled rice samples were 22.92±0.02–19.95±0.02compared to 26.37±0.13for un-treated rice sample. The L-value 21.58 possess for the pressure parboiled treatment ten (PP10). It showed significant difference ($p<0.05$) due to rice that has been parboiled has a distinct colour than rice that has not been parboiled. The transfer of husk colour into the endosperm gives parboiled rice its amber hue. The isomerization of glucose to fructose and the higher levels of reducing sugar and free a-amino nitrogen suggest that non-enzymatic Maillard kind browning may be the cause of the colour change in parboiled rice. In parboiled rice, the quantity of colour change increases as the temperature of the soak water rises, soak time, and steaming time of poorly hydrated grain. At high soaking temperatures, husk colour absorption is also increased, and colored substance absorption from soak water is also severely impacted whiteness of kernels (Oli *et al.,* 2014). Hunter a-values for pressure parboiled samples varied between 6.37 – 3.64 and 6.87 be the un-treated rice sample value. The a-value for treatment which gives overall satisfactory result was 5.36 respectively. It showed a significant difference ($p<0.05$) between control and pressure parboiled samples. The bran and outer endosperm are where the red pigments are concentrated. Rice bran or hull pigments that seep out during soaking in excessive water and spread into the endosperm all through steaming might change the colour of parboiled rice. The degree of parboiling affects the colour changes. The amount of reducing sugar produced by degradation of starch that affect with proteins to give the brown colour in parboiled rice could be the cause of the Maillard browning reaction (Hapsari *et al.,* 2016).

Table 3: Effect of Color attributes on raw and pressure parboiled *Karuppukavuni* rice.

Sr. No.	Sample I.D	Lightness (L) value	Redness (a) value	Yellowness (b) value	DE value
1.	Control	26.37±0.13^{a}	6.87±0.32^{a}	5.41±0.50^{a}	NA
2.	PP1	21.13±0.03^{d}	4.90±0.02^{d}	3.13±0.05^{d}	4.74±0.01^{e}
3.	PP2	21.22±0.07^{d}	4.10±0.02^{gh}	2.88±0.01^{de}	4.97±0.02^{de}
4.	PP3	20.29±0.02^{f}	3.83±0.01^{hi}	2.59±0.03^{ef}	5.63±0.01^{ab}
5.	PP4	22.92±0.02^{b}	6.37±0.04^{b}	4.07±0.04b	3.07±0.01^{g}
6.	PP5	20.78±0.03^{e}	4.40±0.02^{f}	2.64±0.01^{ef}	5.18±0.01^{d}
7.	PP6	20.74±0.03^{e}	4.26±0.02^{fg}	2.88±0.03^{de}	5.19±0.02^{cd}
8.	PP7	20.27±0.03^{f}	4.45±0.02^{ef}	2.54±0.04^{ef}	5.50±0.02^{bc}
9.	PP8	21.15±0.03^{d}	4.71±0.01^{de}	3.60±0.04^{c}	4.70±0.01^{e}
10.	PP9	19.95±0.02^{g}	3.64±0.01^{i}	2.32±0.03^{f}	5.95±0.02^{a}
11.	PP10	21.58±0.03^{c}	5.36±0.03^{c}	3.29±0.02^{cd}	4.32±0.02^{f}

Control – Raw, PP – Pressure parboiled

A statistically significant difference (p<0.05) between the control and different treatments is indicated by different lowercase alphabets in the same column superscript.

A measure of yellowness, showed a significant difference (p<0.05) between control treated samples. b-value with positive values, for the pressure parboiled samples was between 2.32 to 4.07 with the value of 5.41 for un-treated sample. The yellowness was observed to be 3.29 for overall satisfactory treated sample. The b-value showed that the increase in steaming time and soaking duration markedly decrease the yellowness of the sample.

C. Changes in cooking qualities of raw and pressure parboiling of Karuppukavuni rice

The cooking quality characteristics of Karuppukavuni rice were evaluated included cooking time, Gruel solid, water uptake ratio, L/B ratio and cooing coefficient. Highly significant differences (p < 0.05) were noticed for these quality characteristics of differently processed pressure parboiled karuppukavuni rice (Table 4).

Table 4: Effect of cooking qualities on raw and pressure parboiled *Karuppukavuni* rice.

Sr. No.	Sample I.D	Cooking time (minutes)	Water uptake ratio (%)	Gruel solid loss (%)	L/B ratio	Cooking coefficient
1.	Control	76.37 ± 1.98^{f}	2.20 ± 0.04^{d}	5.82 ± 0.06^{e}	1.40 ± 0.02^{a}	0.014 ± 0.001^{c}
2.	PP1	101.72 ± 3.38^{a}	2.35 ± 0.04^{c}	6.90 ± 0.03^{c}	1.09 ± 0.02^{d}	0.015 ± 0.002^{c}
3.	PP2	94.25 ± 3.17^{abcde}	2.40 ± 0.03^{bc}	6.21 ± 0.04^{d}	1.40 ± 0.02^{a}	0.027 ± 0.0^{a}
4.	PP3	100.37 ± 2.52^{ab}	2.72 ± 0.03^{a}	22.25 ± 0.08^{a}	1.0 ± 0.02^{e}	0.009 ± 0.002^{d}
5.	PP4	95.04 ± 3.64^{abcd}	2.66 ± 0.02^{a}	10.29 ± 0.06^{b}	1.09 ± 0.02^{d}	0.018 ± 0.0^{b}
6.	PP5	87.09 ± 2.61^{e}	2.25 ± 0.02^{d}	5.51 ± 0.04^{ef}	0.91 ± 0.01^{f}	0.021 ± 0.0^{b}
7.	PP6	93.89 ± 3.51^{bcde}	2.37 ± 0.02^{bc}	5.63 ± 0.30^{e}	0.83 ± 0.02^{g}	0.012 ± 0.001^{cd}
8.	PP7	87.54 ± 2.67^{de}	2.44 ± 0.03^{b}	5.31 ± 0.04^{f}	1.29 ± 0.02^{b}	0.013 ± 0.0^{c}
9.	PP8	98.83 ± 1.52^{abc}	2.40 ± 0.02^{bc}	5.53 ± 0.04^{ef}	1.17 ± 0.02^{c}	0.013 ± 0.0^{c}
10.	PP9	92.41 ± 1.98^{cde}	2.36 ± 0.02^{bc}	4.33 ± 0.05^{g}	1.18 ± 0.02^{c}	0.018 ± 0.0^{b}
11.	PP10	90.28 ± 1.18^{de}	2.36 ± 0.02^{bc}	6.94 ± 0.05^{c}	1.03 ± 0.02^{de}	0.013 ± 0.0^{c}

Control – Raw, PP – Pressure parboiled

A statistically significant difference (p<0.05) between the control and different treatments is indicated by different lowercase alphabets in the same column superscript.

Cooking time. The temperature of gelatinization and amylose content have a significant impact on the way rice cooks. Rice varieties with an amylose level of higher than 25% absorb larger amount of water during cooking and have a fluffy texture when done. Amylose content determines the texture of cooked rice. The cooking time similarly varied significantly among the differently processed karuppukavuni rice ranging from 76.37±1.98 to 101.72±3.38 min. The rice samples that were pressure parboiled with karuppukavuni had the longer cooking times overall. Since the gelatinization temperature is a direct determinant of the cooking time for rice, the variance in cooking time might be attributed to this temperature. According to some claims, rice cooks more slowly the higher the gelatinization temperature value. According to this study, there is a substantial positive link between cooking time and gelatinization temperatures. As explained by (Bhattacharya & Sowbhagya 1971), Cooking time is largely determined by the rice's milled surface area and is unrelated to other grain characteristics.

Water uptake ratio. The range of values for water uptake ratio varies from 2.20±0.04 to 2.72±0.03. The highest values for water uptake ratio obtained for the pressure parboiled karuppukavuni rice when compared to raw karuppukavuni rice. There may be an amylose component causing the high water uptake ratio, had reported by Frei *et al.* (2003). Rice with a more amylose content has been shown to absorb more water when cooked. The higher moisture content of the rice may possibly be to blame for this. Surprisingly, there was no link with amylose and water uptake ratio. Therefore, further research is required to define the link among both amylose content and water uptake ratio. It is important to note that a higher water uptake ratio has a negative impact on how tasty cooked rice tastes. The stability of the cooked rice is impacted by solids in the cooking water. The difference in values could be due to the different rice consistency, as evidenced by the rupturing of the grains both before and after cooking.

Gruel solid loss. The gruel solid loss was observed to be 5.82% for control sample and for the pressure parboiled treated sample was increase from 4.33% to 22.25%, where the solid loss for optimum treatment was 6.94% showed in (Table 4). Here with the increase in the steaming time decreases the solid content. The outcomes were consistent with those previously reported by (Islam *et al.,* 2001).

L/B ratio. The length-breadth ratio of raw rice was recorded to be 1.40 and the pressure parboiled sample was decreased from 1.40 to 0.83, whereas the value of optimum treatment was 1.03. The L/B ratios of parboiled rice were lesser than un-parboiled cooked rice throughout that both length and width, owing to higher breadth expansion in parboiled rice than raw rice. Parboiled rice has a characteristic short and puffy texture due to its significantly larger expansion along its breadth after cooking (Sujatha *et al.,* 2004).

D. Changes in Textural properties of raw and pressure parboiled Karuppukavuni rice

The textural characteristics of Karuppukavuni rice were evaluated included hardness, cohesiveness, adhesiveness, springiness, gumminess and chewiness. Highly no significant differences ($p>0.05$) were noticed for these quality characteristics of differently processed pressure parboiled karuppukavuni rice (Table 5).

Table 5: Effect of Textural properties on raw and pressure parboiled *Karuppukavuni* rice.

Sr. No.	Sample I.D	Hardness (g)	Cohesiveness (%)	Adhesiveness (g.Sec)	Springiness (%)	Gumminess (g)	Chewiness (g)
1.	Control	216.1±58.8^{c}	0.49±0.00^{a}	-0.08±0.11^{a}	0.84±0.01^{a}	106.8±29.2^{bcd}	90.6±26.5^{ab}
2.	PP1	514.0±15.1^{a}	0.28±0.00^{bc}	-0.97±0.48^{a}	0.84±0.18^{a}	147.63±4.84^{abc}	125.2±31.4^{ab}
3.	PP2	303.5±44.8^{bc}	0.37±0.08^{abc}	-0.06±0.08^{a}	0.84±0.21^{a}	115.7±42.9^{bcd}	102.5±61.6^{ab}
4.	PP3	421.6±27.7^{ab}	0.36±0.03^{abc}	-1.11±0.94^{a}	0.60±0.05^{a}	152.19±5.58^{ab}	92.26±4.30^{ab}
5.	PP4	302.7±29.5^{bc}	0.44±0.01^{ab}	-0.65±0.37^{a}	0.60±0.01^{a}	134.36±8.67^{abcd}	81.50±3.00^{ab}
6.	PP5	391.4±1.2^{abc}	0.48±0.02^{a}	0.00	0.86±0.18^{a}	190.96±10.92^{a}	167.0±44.9^{a}
7.	PP6	546.8±12.7^{a}	0.30±0.07^{bc}	-0.31±0.43^{a}	0.61±0.09^{a}	164.11±2.70^{ab}	101.3±16.7^{ab}
8.	PP7	391.2±0.7^{abc}	0.34±0.00^{abc}	-0.24±0.34^{a}	0.65±0.01^{a}	134.08±3.35^{abcd}	88.49±3.99^{ab}
9.	PP8	236.8±20.7^{bc}	0.32±0.06^{abc}	-0.62±0.25^{a}	0.70±0.04^{a}	76.63±8.91^{cd}	53.48±2.99^{ab}
10.	PP9	501.8±36.9^{a}	0.34±0.02^{abc}	0.00	0.67±0.18^{a}	175.7±26.6^{ab}	121.8±50.0^{ab}
11.	PP10	305.46±2.78^{bc}	0.23±0.02^{c}	-0.97±1.37^{a}	0.39±0.20^{a}	72.40±8.75^{d}	29.5±18.3^{b}

Control – Raw, PP – Pressure parboiled

A statistically no significant difference ($p>0.05$) between the control and different treatments is indicated by different lowercase alphabets in the same column superscript.

Hardness. The hardness of the cooked rice samples are gradually increased from 216.1g for control cooked rice to 546.8 g for pressure parboiled sample treatment six. The optimum treatment sample hardness was recorded to be 305.46 g. This is due to after parboiling, an increase in hardness is the main physical change in the rice kernel. The parboiling temperature and duration significantly affect how hard the rice kernels are. As the soaking temperature and steaming time are raised, the rice kernel's hardness rises in Table 5. The rice grain's tensile properties and flexure strength are also improved by parboiling. The amount of gelatinization and steaming time are directly related to these strength values. The gelatinized starch and damaged protein structures appeared to have grown and absorbed all of the endosperm's air gaps. The enhanced hardness of the endosperm in parboiled rice is most likely due to improved attraction between the molecules within starch granules and protein bodies. The strength gain could explain why parboiled rice breaks down less during milling and has a different texture from non-parboiled rice during the cooking process. Due to the cohesiveness between matrix phase and protein bodies, the parboiling operation occupies blank spaces and repairs cracks in the endosperm, making the rice tougher and minimizing internal fissures, reducing rupture during milling operations (Mir *et al.,* 2015).

Cohesiveness. The term "cohesiveness" refers to the internal resistance of the cooked rice grain (Meng *et al.,* 2018). Here the cohesiveness is recorded to be 0.49 for control sample and it is gradually decreased to 0.23 for the pressure parboiling treatment ten which was the optimized treatment. The degree of milling, amylose content, was all positively and the grain thickness were negatively associated, well with degree of milling impacting this attribute the most. Grain thickness has the smallest impact on cohesiveness values, as the textural qualities of the grain are mostly influenced by its chemical contents (Mohapatra & Bal 2006).

Adhesiveness. The adhesiveness value was observed to be decrease from -0.06 g for the treatment PP2 to -1.11 g for the treatment PP3, where the control sample possess the value of -0.08 g and the optimum pressure parboiled treatment was -0.97 g. Different quantities of moisture absorption into the rice grain during cooking have been ascribed to variation in adhesiveness; a considerable quantity of water penetration into the rice grain leads in improved adhesiveness (Thuengtung& Ogawa 2020). Cooked rice adhesion was determined by the stickiness of the surface. Stickiness, on the other way, was determined by the cooked rice's moisture content and adherent solid content (Islam *et al.*, 2001).

Springiness, Gumminess and Chewiness. As the rice grains are dragged away, the springiness (mm) results correspond to how much they are expanded against the surface contact. The gumminess associate with the quantity of energy required to disintegrate the rice grains to the point where they can be swallowed is governed by the cohesiveness of the cooked rice. Chewiness is a measurement of how much energy it takes to chew rice grains to the point where they can be swallowed (Bhat & Riar, 2017). As indicate in the Table 5 springiness, gumminess and chewiness for the control sample was recorded to be 0.84, 106.8 and 90.6 g respectively. Whereas the optimum pressure parboiled treatment sample was observed to be 0.39, 72.40 and 29.5 g respectively.

E. Changes in Nutritional qualities of raw and pressure parboiled Karuppukavuni rice

(Balbinoti *et al.,* 2018) stated that parboiling rice can boost the amount of biological components in it, making it more nutritious. Proteins, lipids, fibers, and ash levels all increased significantly after parboiling in Table 6. In this study fat, fiber and ash negatively affected by the pressure parboiling process. Whereas, the protein content increases slightly in the pressure parboiled rice from 9.19 gram of protein content of non-parboiled sample to 11.23 gram. The optimized treatment increased minimum amount the protein of 9.77 g. This agree with the statement given in (Rocha-Villarreal *et al.*, 2018) that when compared to untreated grains, the heating temperature and duration parameters enhanced protein content marginally. Higher temperature and pressure while steaming have been linked to oil globule leaching and breaking. The fat content of control sample was 5.89 g which is further decreased during the pressure parboiling process from 5.70g to 2.85 g. The fiber content also reduced significantly during pressure parboiling from 1.04 g for raw rice to 0.90 g for parboiled rice. Rice's crude fat and crude fiber contents may have decreased as a result of unattached oil particles leaking out during hydration through the rice husk's palea and lemma (processed leaves) (Chavan *et al.,* 2018). There is no significant difference ($p>0.05$) in the total carbohydrate content of non-parboiled and parboiled rice. The ash content of control rice sample suggests that temperature has a substantial impact on the ash composition available with no significant difference ($p>0.05$). The finding demonstrates that the ash content of pressure parboiled rice has gradually increased. As the increase in exposure duration of paddy to temperature showed an increase in ash content. This agrees with the statement given by Chukwu & Oseh (2009) reported increase in temperature positively effect on parboiling. The ash value of raw sample was 1.88% which is further increased during parboiling according to duration of temperature subjected to paddy up to 2.78%, whereas the optimum treatment gives ash of 1.95%.

Table 6: Effect of Nutritional qualities on raw and pressure parboiled *Karuppukavuni* rice.

Sample I.D	Protein (g/100g)	Fat (g/100g)	Fiber (g/100g)	Carbohydrate (g/100g)	Ash (%)	Moisture (%)
Control	9.19 ± 0.0^{a}	5.89 ± 1.28^{a}	1.04 ± 0.01^{a}	69.72 ± 1.20^{a}	1.88 ± 0.20^{b}	12.26 ± 0.05^{ab}
PP1	10.21 ± 0.25^{bc}	5.70 ± 0.18^{a}	0.91 ± 0.01^{d}	69.24 ± 0.33^{a}	1.88 ± 0.17^{b}	12.03 ± 0.05^{d}
PP2	10.80 ± 0.25^{ab}	5.33 ± 0.40^{ab}	0.90 ± 0.0^{d}	69.35 ± 0.20^{a}	1.73 ± 0.29^{b}	11.86 ± 0.05^{e}
PP3	10.65 ± 0.25^{abc}	2.85 ± 1.57^{b}	0.92 ± 0.0^{cd}	71.67 ± 1.91^{a}	2.03 ± 0.17^{b}	11.86 ± 0.05^{e}
PP4	9.77 ± 0.25^{cd}	4.49 ± 0.10^{ab}	0.94 ± 0.0^{b}	70.55 ± 0.32^{a}	1.86 ± 0.12^{b}	12.36 ± 0.05^{a}
PP5	10.80 ± 0.25^{ab}	4.50 ± 6.39^{ab}	0.94 ± 0.0^{b}	69.34 ± 0.67^{a}	2.03 ± 0.15^{b}	12.36 ± 0.05^{a}
PP6	10.65 ± 0.66^{abc}	3.68 ± 1.01^{ab}	0.95 ± 0.0^{b}	70.80 ± 1.64^{a}	1.83 ± 0.07^{b}	12.06 ± 0.05^{cd}
PP7	10.21 ± 0.25^{bc}	4.89 ± 0.54^{ab}	$0.910.01^{cd}$	68.99 ± 0.50^{a}	2.78 ± 0.15^{a}	12.20 ± 0.0^{bc}
PP8	11.23 ± 0.24^{a}	4.18 ± 1.04^{ab}	0.94 ± 0.0^{b}	69.51 ± 0.70^{a}	1.95 ± 0.20^{b}	12.16 ± 0.05^{bc}
PP9	10.80 ± 0.25^{ab}	4.33 ± 1.30^{ab}	0.93 ± 0.0^{bc}	69.11 ± 0.98^{a}	2.78 ± 0.15^{a}	12.03 ± 0.05^{d}
PP10	9.77 ± 0.25^{cd}	4.64 ± 0.07^{ab}	0.95 ± 0.0^{b}	71.11 ± 0.34^{a}	1.95 ± 0.21^{b}	11.86 ± 0.05^{e}

Control – Raw, PP – Pressure parboiled
A statistically significant difference ($p<0.05$) between the control and different treatments is indicated by different lowercase alphabets in the same column superscript.

CONCLUSION

The current research was focused on the effect of pressure parboiling method on characteristics of karuppukavuni rice. Among the various treatment conducted with combination of soaking type, soaking time, steaming time and steaming pressure, the treatment 10 which possess the condition of pressure 1.5kg/cm^2, cold soaking type with the soaking duration of 4 hours where the paddy was autoclaved with steaming time of 30 mins, was determined to be the optimum for parboiling. At ideal pressure parboiling position, the head rice yield was increased by 88.84% as compared to non-parboiled raw sample. For a sample that had been treated satisfactorily overall, the yellowness was reported to be 3.29. The b-value demonstrated that the sample's yellowness decreased noticeably as the steaming and soaking times were increased. The parboiling approach lengthened the cooking time (13.91 minutes) due to the rice's increased hardness. Rice's dense structure enhanced water uptake ratio to 0.16 percent while increased gruel solid loss while heating to 1.12 percent. Comparing with control and varies treatment the hardness, cohesiveness, gumminess and chewiness showed a significant difference ($p<0.05$) whereas adhesiveness and springiness has no significant difference ($p>0.05$) in value. Pressure parboiling has a detrimental impact on fat, fiber, and ash. However, rice that has been pressure-parboiled has slightly higher protein content.

FUTURE SCOPE

In order to get other desirable qualities of rice, further investigation of the different sequence of water temperature of soaking, soaking time, and steaming pressure was required.

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REFERENCE

Abdul-Hamid, A., Sulaiman, R. R. R., Osman, A., & Saari, N. (2007). Preliminary study of the chemical composition of rice milling fractions stabilized by microwave heating. *Journal of Food Composition and Analysis*, *20*(7), 627–637.

Alizadeh, M. R. (2011). Effect of Paddy Husked Ratio on Rice Breakage and Whiteness During Milling Process. *Australian Journal of Crop Science*, *5*, 562–565.

AOAC. (2016). Official Methods of Analysis of AOAC International. 20th ed. Association of Analytical Communities, Gaithersburg, MD, USA.

Bhat, F. M., & Riar, C. S. (2017). Physicochemical, cooking, and textural characteristics of grains of different rice (*Oryza sativa* L.) cultivars of temperate region of I ndia and their interrelationships. *Journal of Texture Studies*, *48*(2), 160–170.

Bhattacharya, K. R., & Sowbhagya, C. M. (1971). Water uptake by rice during cooking. *Cereal Science Today*, *16*(12), 420–424.

Chavan, P., Sharma, S. R., Mittal, T. C., Mahajan, G., & Gupta, S. K. (2017). Optimization of parboiling parameters to improve the quality characteristics of Pusa Basmati 1509. *Journal of Food Process Engineering*, *40*(3), e12454.

Chavan, P., Sharma, S. R., Mittal, T. C., Mahajan, G., & Gupta, S. K. (2018). Effect of parboiling technique on physico-chemical and nutritional characteristics of basmati rice. *Agricultural Research Journal*, *55*(3), 490–499.

Chukwu, O., & Oseh, F. J. (2009). Response of nutritional contents of rice (*Oryza sativa*) to parboiling temperatures. *American-Eurasian Journal of Sustainable Agriculture*, *3*(3), 381–387.

Frei, M., Siddhuraju, P., & Becker, K. (2003). Studies on the in vitro starch digestibility and the glycemic index of six different indigenous rice cultivars from the Philippines. *Food Chemistry*, *83*(3), 395–402.

Helmyati, S., & Wigati, M. (2022). The role of rice as a whole grain in the management of metabolic syndrome. In *Functional Foods and Nutraceuticals in Metabolic and Non-Communicable Diseases* (pp. 151–162). Elsevier.

Islam, M. R., Roy, P., Shimizu, N., & Kimura, T. (2002). Effect of processing conditions on physical properties of parboiled rice. *Food Science and Technology Research*, *8*(2), 106–112.

Islam, M. R., Shimizu, N., & Kimura, T. (2001). Quality evaluation of parboiled rice with physical properties. *Food Science and Technology Research*, *7*(1), 57–63.

Jayaraman, R., Uluvar, H., Khanum, F., & Singh, V. (2019). Influence of parboiling of red paddy varieties by simple hot soaking on physical, nutrient, phytochemical, antioxidant properties of their dehusked rice and their mineral, starch, and antioxidant's bioaccessibility studies. *Journal of Food Biochemistry*, *43*(7), e12839.

Kumar, S., & Prasad, K. (2018). Effect of parboiling and puffing processes on the physicochemical, functional, optical, pasting, thermal, textural and structural properties of selected Indica rice. *Journal of Food Measurement and Characterization*, *12*(3), 1707–1722.

Meng, L., Zhang, W., Wu, Z., Hui, A., Gao, H., Chen, P., & He, Y. (2018). Effect of pressure-soaking treatments on texture and retrogradation properties of black rice. *LWT*, *93*, 485–490.

Mir, S. A., Bosco, S. J. D., Shah, M. A., Mir, M. M., &Ganai, S. A. (2015). Rice: parboiling and milling properties. *International Journal of Food Engineering*, *11*(6), 777–787.

Mohapatra, D., & Bal, S. (2006). Cooking quality and instrumental textural attributes of cooked rice for different

Balbinoti, T. C. V., Nicolin, D. J., de Matos Jorge, L. M., & Jorge, R. M. M. (2018). Parboiled rice and parboiling process. *Food Engineering Reviews*, *10*(3), 165–185.
milling fractions. *Journal of Food Engineering*, *73*(3), 253–259.

Noorlaila, A., Nur Suhadah, N., Noriham, A., & Nor Hasanah, H. (2018). Total anthocyanin content and antioxidant activities of pigmented black rice (*Oryza sativa l. japonica*) subjected to soaking and boiling. *Journal Teknologi*, *80*(3).

Oli, P., Ward, R., Adhikari, B., & Torley, P. (2014). Parboiled rice: understanding from a materials science approach. *Journal of Food Engineering*, *124*, 173–183.

Park, J. K., Kim, S. S., & Kim, K. O. (2001). Effect of milling ratio on sensory properties of cooked rice and on physicochemical properties of milled and cooked rice. *Cereal Chemistry*, *78*(2), 151–156.

Raj, D. S., & Sankaran, U. (2021). Rice and diabetes-a comprehensive review. *Romanian Journal of Diabetes Nutrition and Metabolic Diseases*, *28*(4), 437–446.

Raj, S. A., & Singaravadivel, K. (1982). Reduction in Free Fatty Acids Due to Parboiling of Paddy. *Journal of Food Science*, *47*(2), 692–693.

Reddy, U. (2018). exploring the therapeutic potential and nutritional properties of 'KaruppuKavuni' variety rice of Tamil Nadu. *Int J. Pharma. Bio. Sci.*, *9*(1), 88–96.

Rocha-Villarreal, V., Serna-Saldivar, S. O., & García-Lara, S. (2018). Effects of parboiling and other hydrothermal treatments on the physical, functional, and nutritional properties of rice and other cereals. *Cereal Chemistry*, *95*(1), 79–91.

Sivakamasundari, S. K., Moses, J. A., & Anandharamakrishnan, C. (2020). Effect of parboiling methods on the physicochemical characteristics and glycemic index of rice varieties. *Journal of Food Measurement and Characterization*, *14*(6), 3122–3137.

Sujatha, S. J., Ahmad, R., & Bhat, P. R. (2004). Physicochemical properties and cooking qualities of two varieties of raw and parboiled rice cultivated in the coastal region of Dakshina Kannada, India. *Food Chemistry*, *86*(2), 211–216.

Tanaka, Y., & Ohmiya, A. (2008). Seeing is believing: engineering anthocyanin and carotenoid biosynthetic pathways. *Current Opinion in Biotechnology*, *19*(2), 190–197.

Thuengtung, S., & Ogawa, Y. (2020). Comparative study of conventional steam cooking and microwave cooking on cooked pigmented rice texture and their phenolic antioxidant. *Food Science & Nutrition*, *8*(2), 965–972.

Vichapong, J., Sookserm, M., Srijesdaruk, V., Swatsitang, P., & Srijaranai, S. (2010). High performance liquid chromatographic analysis of phenolic compounds and their antioxidant activities in rice varieties. *LWT-Food Science and Technology*, *43*(9), 1325–1330.

Villanova, F. A., El Halal, S. L. M., Vanier, N. L., Polidoro, E., Wang, Y., & de Oliveira, M. (2020). Physicochemical and cooking quality characteristics of South American rice cultivars parboiled at different steaming pressures. *Cereal Chemistry*, *97*(2), 472–482.

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