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Research Article

Physico-Chemical and Cooking Properties of Selected Rice Varieties

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Abstract

Rice is a staple cereal of many ethnic populations of world, especially in South East Asian region. There are many varieties of rice available, which differ in the grain characteristics and cooking quality. Rice is used either as raw or parboiled rice with different degree of polishing. The objective of present study was to analyze ten Indian rice varieties of common use for their physico-chemical characteristics and cooking quality using standard methods. For cooking quality, both pressure and microwave cooking were used. For physico-chemical parameters, the range of values obtained for different rice varieties were as follows: length/width ratio, 1.16-3.25mm; bulk density, 0.401-0.461g/ml; density, 0.786-1.33g/ml; and porosity, 41.36-58.32%. The initial gel consistency was in the range of 28.0–69.5 and after 60 min of setting increased to 33.0-74.5. The maximum equilibrium moisture content for soaked rice at the end of 24 hours ranged between 16.04-19.96%. Amylose content of rice also showed variations ranging from 16% in Ponni boiled rice to 23.2% in Mallige idli rice. The cooking quality of rice samples revealed highest elongation ratio for microwave cooked Mallige idli rice (2.06) and lowest for pressure cooked Basmati rice and Sonamasoori high polish rice (1.06). Most of the rice samples were graded either as 'good' or 'satisfactory' for cooked volume except Gandasala rice which was graded as poor because of low volume. In general, microwave cooking required more water and longer cooking time with lesser cooked volume. In conclusion, the selected rice varieties differed in their physico-chemical characteristics as well as in cooking quality, and hence, can influence the consumer's preferences.

Keywords: Grain Size; Density; Amylose; Gel Consistency; Equilibrium Moisture; Microwave Cooking; Pressure Cooking; Cooking Quality

Introduction

Rice is one of world's major cereal crop and it is used as staple food nearly half of world population. Usually rice is milled and cooked prior to consumption. Its composition may vary depending upon rice varieties. There are more than 1,200 varieties of rice under cultivation throughout the world. The differences in varieties are said to be related to morphology of the plants and grains, resistance to falling, precocity, ramification, productivity, as well as resistance and tolerance to biotic and abiotic factors [1]. Whole grain rice can be of different colors, depending on the variety of rice. Most rice varieties look similar white once they are milled to remove the bran and germ [2]. According to Slaton., *et al.* [3] rice is marketed under three market types designated as long-grain, medium-grain, and short-grain. Varieties of each grain type must confirm within narrow limits to the size and shape specifications established for that type. Thus, grain size and shape are among the first criteria of rice quality that breeders consider in developing new varieties for release in commercial production. If the variety does not conform to recognized standards for grain size, shape, weight, and uniformity, it is simply not considered for release [4,5].

Selection of rice variety depends on their physical characteristics like size and shape. This is due to structure and arrangement of cells in endosperm which are mainly responsible to bring some changes in physical form of rice. If rice has increased girth, it may not be desirable, whereas some rice such as basmati shows high kernel elongation which is desirable and suitable for consumer acceptance. Kernel length also depends on ageing time, gelatinization, hydration etc. Martinez., *et al.* [6] reported that demand by consumers for rice of better quality can also influence its production. Different characteristics of 'grain quality' of rice largely determine the product's market price and acceptability. If the consumer does not like the flavor, texture, aroma, appearance or ease of cooking and processing in a new variety, whatever other outstanding traits it may possess loses its value. The quality of rice is closely related to the quality of its milled whole kernels, since all the domestic rice crop is milled to a high degree.

There are different methods employed for cooking, the two primary factors which influence cooking are water to rice ratio, and controlled heating. Pressure cooking method is considered most acceptable for cooking as steam of high temperature under pressure helps in cooking of rice, and hence it causes minimal losses of nutrients compared to other methods and saves energy [7]. Rice texture is soft and sticky for varieties having low amylose content while rice varieties with high amylose content become stiff and fluffy on cooking [8]. Rice is a major source of carbohydrates, because it contains starch and soluble sugars in it, rice starch is smallest compared to others and is irregular in shape. Starch gelatinization is the major functional characteristic of rice which provides structure and viscosity to its products. The viscosity depends on proportion of amylose to amylopectin, higher the amylose content greater will be the viscosity.

Rice is a staple cereal of Indians and many varieties are grown in the country. They are used in raw or parboiled forms with varying degree of polish and are suitable to different dishes prepared using them. Milling out turn is one of the important properties to the millers. The rice millers prefer varieties with high milling and head rice out turn, whereas consumer preference depend on physico- chemical, cooking and eating qualities [4]. The objective of present study was to determine the physico-chemical characteristics and cooking quality of common varieties of rice grown in India.

Methodology

Materials

Different varieties of rice (*Oryza sativa*) used in the study as described below were procured from local market. The chemicals used for the analysis were all of analytical grade and procured from SD fine chemicals, Rankem, Nice, Fisher Scientific, Qualigens and Loba Chemicals, India.

Selected rice varieties

No.	Name	Abbreviation used	Description
1	Sonamasoori Low Polish	SMLP	Raw, milled with lower degree of polish
2	Sonamasoori High Polish	SMHP	Raw, milled with higher degree of polish
3	Basmati	BR	Raw, milled, polished
4	Mallige Idli	MIR	Parboiled
5	Jaya Parboiled	JPR	Parboiled
6	Manjunatha Steamed	MSR	Steamed
7	Ponni Boiled	PBR	Parboiled
8	Jeera	JR	Raw, milled
9	Rajmudi Unpolished	RUR	Raw, unpolished (brown)
10	Ghandasala	GR	Raw, milled, polished

Table a

Methods

All selected varieties of rice samples were analyzed for physicochemical characteristics and cooking quality. Whole grains were analyzed for length/width ratio, bulk density, 1000 kernel weight, density, porosity and equilibrium moisture content. The raw rice was powdered in a blender and analyzed for gel consistency and amylose content. Further the rice was cooked and analyzed for its quality, water uptake ratio and elongation ratio.

Physicochemical Characteristics of Rice

Following physicochemical characteristics of raw and/or cooked rice grains were determined by techniques mentioned below.

a) **Length/width ratio-** ten kernels of sample were arranged lengthwise and then widthwise for cumulative measurement in centimeters [9].
b) **Bulk density**- the volume in ml of 100g of rice was measured by pouring the grain into a 250 ml measuring cylinder [10].
c) **Density** was determined by displacement of kerosene oil in a 50 ml graduated stoppered test tube. Kerosene oil was poured into test tube up to 20 ml mark, 10 g of grain was added to the tube and the volume noted. It was converted to density as g/ml [11].
d) **1000 Kernel Weight** was determined by weighing 1000 grains of milled rice of each variety [10].

e) **Porosity** is an index of voids in the bulk lots of rice and was calculated from the values of density and bulk density using the following equation:

Porosity% = (Density–Bulk density)/density X 100

f) **Gel Consistency** was measured as consistency of 4.4% (W/V) cold paste. Rice powder (100 mg) was placed into 12×75 mm tubes, followed by 0.2 ml 95% ethanol, 20 ml of 0.2 N KOH and the mixture dispersed. The tubes were placed in a beaker of boiling water to reflux for 8 min with continuously stirring for initial 3 min with the help of a thin glass rod and then left for remaining 5 min. The samples were then removed from the water bath to set at room temperature for 5 min and then cooled in ice water bath for 15 min. The tubes were then laid horizontally over a graph sheet and the length of the gel was measured from the bottom of the test tube to the gel front 30 and 60 min later [12].

g) **Amylose content**: Rice powder (100 mg) was treated with ethanol and sodium hydroxide and heated for 10 min, then cooled and transferred to 100 ml volumetric flask. 5.0 ml of this starch solution was mixed with 1.0 ml of 1N acetic acid and 2.0 ml of iodine solution. The OD was read at 620nm after 20 min [13].

h) **Equilibrium moisture content on soaking** (EMS-S): Rice samples were soaked in distilled water at room temperature. Portions were withdrawn at 0, 15, 30 and 60 min and at 3, 18 and 24 hrs. These were pressed thoroughly between filter paper to remove surface moisture, weighed and dried in oven at 40°C for 24 hrs. The moisture content was determined by repeated weighing and expressed as percentage [14].

Cooking characteristics of rice varieties

Parameters such as soaking time, water uptake, cooking time, cooking quality and cooked rice volume were used to study the cooking characteristics of rice varieties. Rice was cooked optimally by pressure and microwave cooking. The quality of cooked rice was evaluated on basis of water uptake ratio (ml of water absorbed/g of rice), elongation ratio (length of cooked grain/length of uncooked grain) and physical appearance (10). For determining cooked rice volume 100g of rice was gently poured into a graduated cylinder, gently tapping to remove excess of air, reading the volume in ml. The cooking quality was graded as 350 – 375 ml (Poor), 375 – 400 ml (Satisfactory), 400 – 425 ml (Good) and more than 425 ml (Very Good) [15].

Statistical Analysis

The analyzed data were subjected to statistical analysis (mean, standard deviation) using the excel work sheet (Microsoft office 2007).

Results and Discussion

Physico-chemical properties of rice

Common physical properties of rice are size, shape, color, uniformity, and general appearance. Other factors which contribute to general appearance of rice are cleanliness, absence of other seeds, virtuousness, translucency, chalkiness and color, damaged and imperfect kernel. For grain size, length, shape and weight are three main features. The length is the measure of the rough, brown, or milled rice kernel in its highest dimension, while shape is the ratio of length, width, and thickness, and weight is determined by using 1000-kernel weight [2].

The physical characteristics of different types of rice are compiled in table 1. The length of different types of rice ranged from 3.5 to 11.2 mm. Of all the different types of rice, BR was highest in length whereas PBR and RUR were highest in width. JR was least in length and width ratio. As per the classification given by Bhattacharya., *et al*. [16] based on grain dimensions (shape and L/B ratio), and also Houston [2], rice grain up to length of 5.5 mm, are considered as small rice, between length of 5.51 mm to 6.6 mm as medium grain, and between length ranging from 6.61 mm to 7.5 mm as long grain rice. Therefore, according to the data obtained, GR and JR belong to short grain rice, PBR, MSR, MIR to medium rice grain, and SMLP, SMHP, JPR, RUR and BR to long grain rice.

BR is the largest rice compared to other rice varieties tabulated, it is also known as scented rice, because it gives characteristic aroma, due to presence of bioactive compounds present in it. When cooked it swells only lengthwise, resulting in long slender grains that are very dry, light and separate and not sticky. The grains of Basmati are longer than most other types of rice. It has characteristic property, of resulting in a grainy separate appearance when it is cooked. This property is suitable for rice dishes which need grainy texture. Cooked grains of Basmati rice are characteristically free flowing rather than sticky [9,17]. Khatoon and Prakash [18] reported a length-width ratio of BT rice, Gowrisanna, JR, BR as 2.84, 2.64, 2.21 and 4.12 respectively and Khan and Reddy [19] reported a ratio of 2.6 to 4.0 for different rice varieties.

Bulk density (BD) of any material indicates the weight/volume ratio and is an important parameter from storage point of view. The data of BD are important in the calculation of the dimension of bulk storage facilities; it also indicates the purity-degree of the grains since the presence of light foreign matter reduces the grain density. BD is an important physical property of rough and milled rice and is

Type of Rice		L/W Ratio (mm)			Bulk Density (g/ml)	1000 Kernel Weight (g)	Density (g/ml)	Porosity (%)
		L (mm)	W (mm)	L/W (mm)				
1	SMHP	7.30	2.5	2.92	0.430 ± 0.002	28.94 ± 0.96	1.033 ± 0.25	58.32
2	SMLP	7.17	2.2	3.25	0.441 ± 0.002	19.53 ± 1.11	0.963 ± 0.11	54.19
3	JPR	8.00	3.5	2.28	0.445 ± 0.004	31.55 ± 3.03	1.330 ± 0.08	66.52
4	MIR	6.60	3.7	1.78	0.481 ± 0.004	35.26 ± 0.94	1.330 ± 0.18	41.36
5	MSR	5.50	1.9	2.89	0.401 ± 0.002	22.81 ± 2.36	0.983 ± 0.03	59.19
6	PBR	6.10	4.4	1.38	0.440 ± 0.004	23.47 ± 1.18	0.953 ± 0.11	53.85
7	RUR	7.00	4.5	1.55	0.450 ± 0.006	27.72 ± 1.21	0.893 ± 0.03	49.55
8	JR	3.50	3.0	1.16	0.449 ± 0.006	16.61 ± 1.49	0.880 ± 0.05	48.94
9	BR	11.20	3.8	2.94	0.404 ± 0.006	25.32 ± 3.05	0.873 ± 0.06	44.89
10	GR	3.60	2.5	1.44	0.461 ± 0.004	19.67 ± 1.08	0.786 ± 0.05	66.70

Table 1: Physical characteristics of different types of rice.

dependent on grain type (long, medium, or short-grain), moisture content, kernel density, and additional physical properties such as kernel shape and dimensional characteristics. The BD of various rice varieties in present study ranged from 0.401 to 0.481g/ml.

Bhattacharya., *et al.* [11] reported that as moisture content increased, kernel density and BD of rough rice increased, whereas that of brown rice decreased. They noted that BD is related to the kernel shape (i.e., length-to-width ratio); the more round the kernel, the greater the BD and the lower the porosity. These were related to the grain shape (l/b ratio); the more round the grain, the greater was the BD and lower the porosity, it was vice versa. Density of rice increased slightly with milling; but BD and porosity were markedly affected by the degree of milling. The range of values reported by Khatoon and Prakash [18] for BD were slightly higher at 0.781-0.860 g/ml. In general, with progressive milling, BD decreased at first and then increased, while porosity changed in reverse fashion, the changes being more pronounced in parboiled rice than in raw rice.

The 1,000 grain weight provides information about the size and density of the grain. Grains of different density mill differently and are likely to retain moisture differently and cook differently. Uniform grain weight is important for consistent grain quality. The 1000 kernel weight ranged from lowest value of 16.61g (JR) to highest of 35.26g (MIR). The 1000 Kernel weight of JPR was 31.55g. Parboiling results in significant changes in the physico-chemical and cooking characteristics of rice grain [20]. The range of 1000 kernel weight for scented rice varieties was reported to be 15.82-26.80g [21] and for Basmati brands, it was 1.59-1.64g [17]. Density of milled rice ranged from lowest of 0.786g and highest of 1.330g. Density depends on type of rice grain. Porosity, the index of voids was highest in MIR, and least in GR. Porosity of rice depends on density and bulk density and indicates the storage properties.

Gel consistency, which is a measure of cold paste-viscosity of cooked milled rice flour, is a good index of cooked rice texture, especially among rice of high amylose content. Rice differs in gel consistency from soft to hard. Gel consistency measures the tendency of cooked rice starch to harden after cooling; varieties with softer gels have higher degree of tenderness when cooked. Harder gel consistency and firmer cooked rice are associated with high amylose rice. Hard cooked rice also tends to be less sticky. Hard gel consistency is represented by shorter gel while soft gel consistency tends to be associated with longer gel. The gelatinization ability of starches is influenced by many parameters such as the amylose: amylopectin ratio, the degree of hydration, and the size of starch granule. Gel consistency differs depending upon the source of starch and variety of grain. Cooked rice with hard gel consistency hardens faster than those with a soft one. Rice with soft gel consistency cook tender, and remain soft even upon cooling. Rice with soft gel consistency is preferred by most consumers [10,22].

The gel consistency of different rice varieties are presented in Table 2. Different rice had different gel consistency depending on the water uptake, and with increase in time the consistency also increased. Parboiled rice gave a higher consistency when compared to the other types of rice, hence it had a softer gel strength. Polishing of rice also varied the gel consistency, because as observed

SMHP rice was harder than the SMLP. As the water holding capacity decreased the rice became harder in consistency. SMHP, BR and GR showed similar gel consistency with hardness in texture. The gel consistency reported by Sarkar [21] ranged from 22 to 78 mm for scented and non-scented varieties. Khatoon and Prakash [18] reported a range of 27-29 mm for different varieties.

Rice variety		Gel consistency					
		Initial	Consistency	30 min	Consistency	60 min	Consistency
1	SMHP	28.0± 0.2	Hard	46.7 ± 0.3	Medium	54.0 ± 0.1	Medium
2	SMLP	54.6 ± 0.4	Medium	58.5 ± 0.5	Medium	58.9 ± 0.7	Medium
3	JPR	69.5 ± 0.1	Soft	73.9 ± 0.2	Soft	74.5 ± 0.7	Soft
4	MIR	38.0 ± 0.0	Medium Hard	58.0 ± 0.1	Medium	62.5 ± 0.7	Soft
5	MSR	37.8 ± 0.2	Medium Hard	45.0 ± 0.0	Medium	48.0 ± 0.0	Medium
6	PBR	36.0 ± 0.0	Medium Hard	50.0 ± 0.1	Medium	54.6 ± 0.8	Medium
7	RUR	28.4 ± 0.7	Hard	33.0 ± 0.2	Hard	37.0 ± 0.0	Medium Hard
8	JR	30.4 ± 0.7	Hard	31.5 ± 0.8	Hard	34.5 ± 0.7	Hard
9	BR	28.0 ± 0.0	Hard	33.7 ± 1.0	Hard	36.0 ± 0.0	Medium Hard
10	GR	29.4 ± 0.7	Hard	32.0 ± 1.4	Hard	33.0 ± 0.0	Hard

Table 2: Gel Consistency of different types of rice.

Equilibrium moisture content of ten different types of rice were determined, for eight time variations of soaking as can be seen in table 3. At 0 min, with no soaking, the moisture content in SMHP rice was 1.88%, in SMLP rice, it was 3.0% and in JPR it was 3.82%. Thus the equilibrium moisture content measured as hydration capacity of rice varieties presented in Table 3 shows that initial moisture content of samples varied between 1.88 to 7.56%. Maximum increase was observed within 15 min of soaking in water and the samples continued to absorb some more water as the soaking time increased. The maximum hydration range was 16.04 to 19.96% for different varieties. Khatoon and Prakash [18] reported that maximum water uptake happened in first 15 min with the samples reaching an equilibrium state after 30 min and maximum moisture uptake of 29.1% was for basmati rice.

Rice variety		0 min	15 min	30 min	60 min	3 hr	6 hr	18 hr	24 hr
1	SMHP	1.88±0.8	9.86±1.6	10.07± 0.1	15.65±0.2	16.00±0.1	16.70±0.3	18.59±0.1	19.78±0.0
2	SMLP	4.12±0.85	5.66±0.8	9.44±0.3	9.76±0.4	10.00±0.3	12.34±0.0	14.58±0.3	16.04±1.4
3	JPR	7.82±0.4	8.97±1.9	8.99±0.1	9.94±0.3	14.00±0.2	16.80±0.1	18.39±0.4	19.96±0.1
4	MIR	3.87±1.0	10.56±0.7	14.75±0.6	15.36±1.2	18.00±0.6	18.70±0.3	19.33±0.3	19.95 ±0.0
5	MSR	3.36 ± 0.1	5.26±0.1	5.86±1.4	5.65±0.0	10.00±1.2	14.70±0.3	16.53±0.2	18.25±0.1
6	PBR	3.97±0.1	9.40±0.0	9.42±0.4	9.74±0.4	11.00±0.4	15.80±0.0	17.65±0.1	18.92±0.8
7	RUR	2.10±0.03	5.10±0.5	7.36±1.0	8.97±1.3	10.00±0.8	12.50±0.2	15.78±0.1	16.63±0.6
8	JR	3.56±0.7	4.56±0.7	7.04±0.1	8.15±0.6	8.20±0.1	11.70±0.0	12.23±0.0	16.04±0.0
9	BR	1.79±0.8	4.13±0.0	4.67±0.1	6.07±1.2	10.00±0.1	13.70±0.6	16.55±0.6	17.88±0.2
10	GR	2.64±0.4	7.45±1.3	9.83±0.6	11.28±1.6	13.00±0.4	14.00±1.0	16.30± 0.6	17.04±0.0

Table 3: Equilibrium moisture content (%) of different types of rice.

Amylose content is recognized as the most important determinant of rice quality [23,24]. Amylose content in SMHP rice was 22 ± 0.01g/100g. SMLP rice had 21% amylose. Sarkar., *et al*. [21] reported the amylose content for scented rice varieties to be 16.37 to 20.13% and for non-scented varieties, 13.40 to 25.21%. Khatoon and Prakash [18] mentioned a range of 20-23.8 for the analyzed rice samples. Differences in the amylose content are attributed to characteristics for varieties and in part to the differences in the environmental conditions in which the crop is grown, particularly temperature. Hettiarachchy, [25] stated a range of 21.6 to 35.7% of amylose content in rice. It has been reported that amylose content is positively correlated with elongation ratio [26].

Rice variety		Amylose (g/100g)	Rice variety		Amylose (g/100g)
1	SMHP	22.0 ± 0.01	6	PBR	16 .0 ± 0.01
2	SMLP	21.0 ± 0.00	7	RUR	22.6 ±0.02
3	JPR	21.0 ± 0.01	8	JR	17.6 ± 0.05
4	MIR	23.2 ± 0.00	9	BR	19.4 ± 0.00
5	MSR	18.9 ± 0.00	10	GR	20.5 ± 0.00

Table 4: Amylose content in different varieties of rice.

Cooking characteristics of rice

Ten different rice varieties were optimally cooked by pressure and microwave cooking, and the related data is compiled in table 5. Soaking time for the rice variety was standardized using biting test. [This test is based on the concept that fully hydrated rice grain does not make any sound on biting.] Soaking time depended on the type of rice. SMHP rice was soaked for 20min, and amount of water used for cooking was 245 ml for pressure cooking and 425ml for microwave oven cooking. Water uptake ratio is mainly influenced by water absorbing or water imbibing capacity of rice samples. Microwave cooking required more water and had more of unabsorbed water compared to pressure cooking. Cooked weight of pressure cooked samples was more than microwave cooked samples, as rice absorbs more water under pressure and evaporation loss is minimum.

Rice variety	Method of cooking		Soaking time (min)	Water used (ml)	Water uptake ratio	Cooking time (min)	Cooked weight (g)	Length of cooked grain (mm)	Length of uncooked grain (mm)	Elongation ratio	Cooked rice Volume (ml)	Quality	Physical appearance
1	SMHP	PC	20	245	2.4±0.25	20	358	3.5	3.3	1.06	412	Satisfactory	Intact
		MC	20	425	4.2±0.25	25	342	3.8	3.4	1.11	385		Broken
2	SMLP	PC	20	245	2.3±0.25	20	342	6.8	5.3	1.28	428	Good	Intact
		MC	20	425	4.0±0.25	25	338	6.5	5.6	1.16	415		Separate
3	JPR	PC	32	325	3.2±0.25	28	428	7.5	4.2	1.78	412	Satisfactory	Intact
		MC	32	525	5.2±0.25	36	418	6.3	4.4	1.43	385		Separate
4	MIR	PC	40	300	3.0±0.00	28	353	7.3	6.8	1.07	430	Good	Intact
		MC	40	553	5.5±0.00	32	339	6.2	3.0	2.06	410		Separate
5	MSR	PC	38	400	4.0±0.52	33	325	4.0	3.8	1.05	432	Good	Flaky
		MC	38	612	6.1±0.28	42	319	3.0	2.5	1.20	415		Broken
6	PBR	PC	36	425	4.3±0.75	30	334	5.5	4.2	1.30	450	Good	Separate
		MC	36	600	6.0±0.33	38	322	4.0	3.1	1.32	408		Broken
7	RUR	PC	30	512	5.1±0.60	20	322	6.8	6.2	1.09	485	Good	Separate
		MC	30	698	6.7±0.42	28	315	5.5	4.2	1.30	411		Separate
8	JR	PC	20	300	3.0±0.40	15	320	4.0	3.3	1.21	400	Good	Separate
		MC	18	520	5.2±0.50	20	311	3.0	2.8	1.07	376		Flaky
9	BR	PC	18	320	3.2±0.23	8	344	11.2	10.5	1.06	435	Good	Separate
		MC	22	525	5.3±0.30	18	331	9.2	8.5	1.08	329		Flaky
10	GR	PC	24	280	2.8±0.30	8	338	4.2	3.3	1.27	355	Poor	Grainy
		MC	24	425	4.3±0.18	24	325	3.2	2.5	1.28	332		Separate

Table 5: Cooking characteristics of different varieties of rice.

PC: Pressure cooked, MC: Microwave cooked.

Parboiled rice is rough rice that has been subjected to a steam or hot water treatment prior to milling; parboiling increases the percentage of head rice and the vitamin content of milled rice. This procedure gelatinizes the starch in the grain, and results in firmer more separate grains. It also takes a few minutes longer to cook [27]. Unpolished or brown rice is the least processed form of rice because only the husk is removed and the bran layers remain; thus giving it its color and nutty flavor. The presence of the bran makes brown rice rich in nutrients. Brown rice contributes good nutritional properties as it contains considerably higher amounts of proteins and minerals than rice [28]. Therefore, brown rice flour would be an ideal raw material for the production of gluten-free products, i.e. breads. However, rice proteins do not possess the visco-elastic properties typically found in gluten, thus making rice flour unsuitable for the production of yeast-leavened products. For this reason, hydrocolloids and gums are generally used as gluten replacements to confer structure and gas-retaining capacity to rice batters [29].

According to Sowbhagya and Ali [30], presoaking at room temperature for 15 min for raw rice decreased cooking time by 50% as compared to unsoaked controls. Elongation ratio observed was 1.06, and elongation behavior on cooking revealed that water uptake was the only character showing a positive and significant influence on kernel elongation. In microwave cooked samples elongation ratio was 0.9. The amylose content of rice varieties exerts an influence on elongation ratio when cooked in a microwave oven. Cooked rice volume was higher in pressure cooked samples indicating better quality than the microwave cooked samples. The physical appearance of pressure cooked rice showed separate grains, whereas microwave cooked rice had a flaky appearance. Yiu., *et al.* [31] reported that microwave cooked rice grain was firmer when compared to pressure cooked samples. This may be because of lack of maximum imbibitions of water or due to inadequate starch gelatinization because microwave cooking produced less dispersed gelatinized starch than did conventional cooking. Similar findings were reported by Khatoon and Prakash [32].

Good cooking rice variety had water absorption rate from 175% to 275%. Cooking quality of rice depends upon the 2 main components in rice grain that is amylose and amylopectin. Siddhu., *et al.* [10] reported that cooking of rice in pressure cooker causes more elongation due to hydration of water, than compared to microwave cooking. Higher elongation value ranges from 1.80-1.94, and lower in microwave 1.49-1.67, thus expansion and hydration is better in pressure cooking than microwave cooking. Kernel elongation and aroma of rice is mainly influenced by the presence of gene in chromosome. Thus elongation is physical phenomenon and it depends on ageing time, temperature, hydration, and gelatinization temperature [32].

Conclusions

Different varieties of rice showed variation in physico-chemical properties. In case of length/width ratio there was not much difference between sample. MIR had highest bulk density than compared to the other varieties. JPR had more gel front and thus it depicts that its consistency is soft. In case of equilibrium moisture content, JPR had more moisture absorbing capacity of about 19.96% and least was observed in JR of about 16.04%. MIR was rich in amylose content of 23.2%, whereas PBR had least amylose (16.0%). Cooking characteristics of ten different varieties of rice showed good and satisfactory quality except for Ghandasala rice which was poor in cooking quality. Overall results indicate that the rice samples varied considerably in their physicochemical parameters and cooking quality, which could influence the selection by consumer as consumers have their own preferences for the quality of rice they use.

Author Contribution

1. Ms. Megha CP: Graduate student, who worked on this project.
2. Ms. Divya Ramesh: Research Scholar, who assisted in laboratory work.
3. Dr. Jamuna Prakash: Research supervisor in charge of guiding the research project.

Conflict of Statement

The authors have no conflict of interest in publishing this paper.

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