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Chemical and nutritional composition of traditional rice varieties of Karnataka

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Abstract
Rice (*Oryza sativa* L.) is a very popular food crop in the world. Easy digestibility and nutritional properties, rice is highly preferred over other cereals. Evaluation of twenty traditional rice varieties grown in Karnataka, as a dehusked grain was performed with respect to chemical and nutritional characteristics. Traditional rice varieties varied significantly ($p<0.05$) for all the parameters studied. Moisture (8.44-10.04%), protein (7.63-12.35%), Fat (2.12-3.23%), Fibre (1.29-3.16%), Ash (1.08-1.64%), carbohydrate (72.85-77.53%), and energy (353.16-366.91 Kcal) content of traditional rice varieties differed significantly. Minerals viz., iron (1.34-3.36 mg), zinc (2.22-3.72 mg), calcium (18.32-24.07 mg), and phosphorus (225.25-248.41 mg) differed significantly. Amylose and total starch content ranged from 12.51 to 24.64 per cent and 68.31 to 75.64 per cent respectively. Insoluble, soluble and total dietary fibre ranged from 4.34 to 9.79, 0.12 to 0.62, and 4.46 to 10.40 g per 100 g respectively. This is the first report on systemic analysis of chemical and nutritional qualities of traditional rice varieties of Karnataka.

Keywords: Traditional rice varieties, nutritional, chemical

Introduction
Rice (*Oryza sativa* L.) is one of the major food crops in the world and more than 50 per cent of the world's population depend on rice as their primary calorie source [1] and increasingly becoming popular because of its nutritional and beneficial health properties [2]. Commonly, rice is consumed as polished white rice with the husk, bran, and germ fractions removed. However, consumption of brown rice (hulled rice) is gaining lot of importance in recent years, due to the increased awareness about its health benefits and good nutritional properties and higher amounts of proteins, ash, dietary fibre as well as minerals than white rice [3-5]. Through the introduction of modern high yielding varieties, along with new management practices and green revolution has led to a considerable increase in rice production in India as in other Asian countries. This development has led to a gradual erosion of the rice genetic diversity, since thousands of traditional rice varieties were replaced by relatively few high yielding rice varieties [6]. Traditional rice varieties have long been consumed in Asian countries viz., India, Sri Lanka, China, Japan, etc [7-9]. Being a major cereal grain, evaluating the nutritional composition of rice has been given highest priority[10]. Rice grain quality is reported to be influenced by various physico-chemical and cooking characteristics [11, 12]. Providing adequate information on the quality of rice consumed by local population is important for health conscious consumer. Variety with best grain properties remains the most important determinant of market grading and end use qualities. However, studies have not been carried out comprehensively on nutritional composition of the traditional rice varieties in Karnataka, India. To encourage traditional rice cultivation in India, there is need for a systematic study that would reveal nutritional qualities from traditional rice varieties and would stand the world market competitiveness. Thus keeping in view of above facts, the present research work was undertaken to analyse chemical composition of traditional rice varieties of Karnataka.

Materials and methods
Procurement of traditional paddy rice varieties: Twenty traditional rice varieties were procured from All India Coordinated Research Project on Rice, ZARS, V. C. Farm, Mandya, Karnataka. The different genotypes used for the study are, *Gamnad batta, Anandi, Krishnaleela, Kagisaale, Murakan sanna, Mysore mallige, Nagabatta, Gajagunda, Doddabyranellu, Ratnachoodi, Malgudi sanna, Gowrisanna, Chinna ponni, Salem sanna, Karimundaga, Rajmudi, Rajakaime, Jeerige sanna, Gandhasaale, Kalajeera*.

Milling: Paddy samples were cleaned thoroughly using winnower to remove the chaff and other foreign matters and dried in hot air oven up to 12-14% moisture content and de-husked using a rubber roll paddy sheller at the Department of Post-Harvest Technology, UAS, GKVK, Bengaluru. Milling fractions include husk, head rice, bran, and broken rice. Only whole rice grains without any physical damage or insect infestation were selected for the study. Further, rice samples (Head rice) were individually ground to a fine powder (60 mesh size), packed in air tight polyethylene plastic bags and were stored at 4 °C until further analysis.

Rice grain classification

Milled rice was first classified into three categories based on length, long (>6 mm), medium (5-6 mm), and short (<5 mm). They were again classified into three groups based on the length/breadth ratio; 1) slender (>3); 2) bold (2-3); 3) round (<2) to determine size and shape [13].

Chemical and nutritional characteristics of traditional rice varieties

Traditional rice varieties were analysed for proximates, mineral composition, sugars, and dietary fibre composition. IR 64 is one of the most cultivated hybrid rice variety in Asia [14] known for its palatability and high yield [15] and widely consumed in South India [16]. IR 64 continued to be the variety of choice among traders and processors [17]. Thus, for the components viz., proximate, mineral composition and dietary fibre fractions, the IR 64 rice variety was compared with the values of traditional rice varieties.

Proximate composition: All samples were analysed in triplicate for their proximate composition by AOAC methods [18]. Carbohydrate content was calculated by differential method and energy composition was computed.

Mineral composition: The selected traditional rice samples were dried in a hot air oven, powdered and ashed in muffle furnace at 550 ºC for ten hours and ash was dissolved in HCl. Calcium and Phosphorous contents were estimated by AOAC methods [19]. Iron and zinc contents were estimated by using atomic absorption spectrophotometer [20].

Free sugars: Reducing and total sugar contents were estimated titrimetrically according to Shaffer-Somogyi methods [19].

Dietary fibre analysis

The amounts of total dietary fibre (TDF), soluble dietary fibre (SDF), and insoluble dietary fibre (IDF) of the rice samples were determined using following procedures [18].

Estimation of insoluble dietary fibre (IDF)

Defatted samples were gelatinized and starch was removed by enzymatic digestion. The residue was quantified gravimetrically.

$$\text{IDF (\%)} = \frac{\text{Wt. of the IDF residue (g)} - \{\text{Protein (g) in IDF residue} + \text{Ash (g) in IDF residue}\}}{\text{Wt. of the sample (g)}} \times 100$$

Estimation of soluble dietary fibre (SDF)

The soluble fibre was estimated in the filtrate obtained after enzymatic digestion of protein and carbohydrate of defatted food. The soluble fibre was precipitated and quantified gravimetrically.

$$\text{SDF (\%)} = \frac{\text{Wt. of the SDF residue (g)} - \{\text{Protein (g) in SDF residue} + \text{Ash (g) in SDF residue}\}}{\text{Wt. of the sample (g)}} \times 100$$

Estimation of total dietary fibre (TDF)

The total dietary fibre was the sum of the insoluble and soluble dietary fibre. It was estimated as follows;

$$\text{Blank \%} = \text{wt. of the blank residue (g)} - \{\text{protein (g) in the blank residue} + \text{Ash (g) of the blank residue}\}$$

Total Dietary Fiber = IDF + SDF values

Starch and Amylose: Total starch content was analysed by the method of AOAC (2009). Amylose content in rice samples were determined based on the Iodine-binding procedure as described by Juliano [21].

Results and Discussion

Nutrient composition of traditional rice varieties

Nutrient composition of traditional rice varieties are shown in Table 1 to 9. The results are explained in following paragraphs.

Proximate composition

The results obtained for proximate composition of different traditional rice varieties are depicted in Table 1. The proximate composition of traditional rice varieties were compared with very popular variety IR 64 rice values specified by Deepa [22]. Significant differences were recorded in the proximate composition between varieties of rice evaluated and results are expressed in terms of g per 100g. Energy value is expressed in terms of Kcal.

Moisture (per 100g)

Moisture content, which plays a significant role in determining the shelf-life varied between 8.44 to 10.04 g per 100 g [23]. Irrespective of grain type, moisture content was found maximum in Dodabyranallu (10.04 g), however no significant mean difference was observed with varieties Krishnaleela (8.61 g), Murkan sanna (8.83 g) and Gajagunda (9.82 g). These values correspond to the Yodmanee *et al.* where it ranged from 5.96 to 8.19 g/100 g (db) [24].

Protein (per 100g)

In rice nutrition, rice protein has gained great attentions due to its relatively well balanced amino acid profile, which is superior in lysine content to wheat, corn, millet, and sorghum [25]. Among all the rice varieties tested, Malgudi sanna (12.35 g) recorded highest protein content followed by Gandhasaale (11.23 g) and Rjakaime (10.49 g) and least was observed in Rajmudi (7.63 g). Prior researches reported that environmental factors such as crop season, location, fertilization reaping, drying, and storage methods affected the protein content of rice [26, 27, 28, 29]. International Rice Research Institute (IRRI) analyzed the protein content of 2869 rice varieties. Protein content ranged from 4.5 to 15.9 per cent in *Oryza sativa* varieties and 10.2 to 15.9 per cent in *Oryza glaberrima* varieties.

Fat (per 100g)

The lipid content in traditional rice varieties was higher than those reported in Mexican rice cultivars (0.47-1.22%) [30]. The lower lipid content determined in those cultivars is due to that rice was polished and maximum amount of lipids present in bran was removed. In the present study, overall, short grain rice variety Jeerige sanna (3.23 g) recorded highest fat content and least was observed in long grain variety Gajagunda (2.12 g). The difference in lipid content among samples may result in part from the variety and crop year. It has been reported by Taira and Chang that brown rice contains considerable amounts of essential fatty acids and that most of the fat is contained in the bran [31].

Fibre (per 100g)

The crude fibre content was found significantly highest in Doddabyranellu (3.16 g) followed by Gajagunda (3.11 g) and least was observed in Nagabatta (1.29 g). Yodmanee *et al.* [24] reported crude fibre content in the range of 0.16 to 0.35 g/100g. In the present study higher values were reported for traditional rice varieties. However Anjum *et al.* [32] recorded slightly higher values (2.17-2.57%). This might be due to brown rice contained higher percentage of bran than white rice, milling strips off the bran layer, leaving a core comprised of mostly starch endosperm.

Ash (per 100g)

The amount of ash present in a food sample plays an important role while determining the levels of essential minerals [33]. Ash content was high in short grain rice variety Jeerige sanna (1.64 g). However, most of the rice varieties did not show significant difference in mean ash content. This might be explained that ash content may be different in milling fractions due to degree of severity during milling for the separation of bran [32]. In this study traditional rice varieties were not polished hence higher values for ash content were reported. Yodmanee *et al.* reported similar values [24].

Carbohydrate (per 100g)

The carbohydrate calculated by difference was found to vary between 72.85 to 77.53 g. Irrespective of grain type, Rajmudi (77.53 g) recorded highest carbohydrate content and least was observed in Malgudi sanna (72.85 g). Thomas *et al.* found slightly higher values and ranged from 78.21 to 82.23 per cent in locally grown and improved rice varieties of Penang [34]. However, the values showed in the present study were within the range reported by Deepa *et al.* [22].

Energy (per 100g)

Energy value measures the available amount of energy obtained from food via cellular respiration. In this study Rajmudi (366.91 Kcal) rice variety provided the highest energy per 100 g among all the rice varieties studied and least was provided by Gajagunda (353.16 Kcal). Similar findings for energy value was reported by Ebuehi and Oyewole in raw indigenous ‘*ofada*’ rice (351.8 Kcal) and foreign ‘*arosa*’ (359.8 Kcal) rice varieties in Nigeria [35].

Table 1: Proximate composition of traditional rice varieties per 100g

Category	No.	Varieties	Moisture (g)	Protein (g)	Fat (g)	Fibre (g)	Ash (g)	#Carbohydrate (g)	Energy (Kcal)
Long grain	1	Gamnad batta	9.60 ^{abc}	9.06 ^{fg}	2.44 ^{cdef}	1.87 ^{g}	1.32 ^{fg}	75.70 ^{cde}	361.06 ^{fg}
	2	Anandi	9.44 ^{bcd}	10.07 ^{cd}	2.60 ^{cd}	2.27 ^{e}	1.43 ^{cdefg}	74.19 ^{f}	360.43 ^{fgh}
	3	Krishnaleela	8.61 ^{ghi}	8.25 ^{i}	2.54 ^{cde}	3.09 ^{a}	1.53 ^{abc}	75.98 ^{cde}	359.80 ^{gh}
	4	Kagisaale	9.34 ^{bcde}	8.51 ^{hi}	2.14 ^{g}	2.78 ^{b}	1.45 ^{bcde}	75.79 ^{cde}	356.41 ^{i}
	5	Murakan sanna	8.83 ^{fghi}	8.31 ^{i}	2.63 ^{c}	2.37 ^{d}	1.51 ^{bcd}	76.35 ^{bc}	362.34 ^{def}
	6	Mysore mallige	8.64 ^{ghi}	8.66 ^{ghi}	2.38 ^{cdefg}	2.56 ^{c}	1.45 ^{bcdef}	76.31 ^{bcd}	361.32 ^{efg}
	7	Nagabatta	8.96 ^{defg}	9.63 ^{d}	2.44 ^{cdef}	1.29 ^{i}	1.43 ^{bcdefg}	76.25 ^{bcde}	365.45 ^{abc}
	8	Gajagunda	9.82 ^{ab}	7.64 ^{j}	2.12 ^{g}	3.11 ^{a}	1.44 ^{bcdef}	75.88 ^{cde}	353.16 ^{j}
Medium grain	9	Doddabyranellu	10.04 ^{a}	8.51 ^{hi}	2.59 ^{cde}	3.16 ^{a}	1.56 ^{ab}	74.14 ^{f}	353.89 ^{j}
	10	Ratnachoodi	8.93 ^{efgh}	8.60 ^{ghi}	2.63 ^{c}	1.82 ^{g}	1.08 ^{h}	76.94 ^{ab}	365.85 ^{ab}
	11	Malgudi sanna	8.90 ^{efghi}	12.35 ^{a}	2.25 ^{fg}	2.32 ^{de}	1.34 ^{efg}	72.85 ^{g}	361.01 ^{fg}
	12	Gowrisanna	8.44 ^{i}	8.60 ^{ghi}	2.55 ^{cde}	2.16 ^{f}	1.45 ^{bcde}	76.80 ^{ab}	364.55 ^{bcd}
	13	Chinna ponni	8.91 ^{efghi}	9.19 ^{ef}	2.58 ^{cde}	2.50 ^{c}	1.31 ^{g}	75.51 ^{e}	362.07 ^{ef}
	14	Salem sanna	8.48 ^{hi}	8.34 ^{i}	2.32 ^{efg}	2.10 ^{f}	1.49 ^{bcd}	77.26 ^{a}	363.34 ^{cde}
	15	Karimundaga	8.66 ^{ghi}	8.86 ^{fgh}	2.35 ^{defg}	3.09 ^{a}	1.50 ^{bcd}	75.54 ^{de}	358.71 ^{h}
	16	Rajmudi	8.72 ^{ghi}	7.63 ^{j}	2.92 ^{b}	1.82 ^{g}	1.38 ^{defg}	77.53 ^{a}	366.91 ^{a}
Short grain	17	Rajakaime	9.22 ^{cdef}	10.49 ^{c}	2.61 ^{cd}	2.35 ^{de}	1.47 ^{bcde}	73.86 ^{f}	360.87 ^{fgh}
	18	Jeerige sanna	8.68 ^{ghi}	8.61 ^{ghi}	3.23 ^{a}	2.17 ^{f}	1.64 ^{a}	75.67 ^{cde}	366.15 ^{ab}
	19	Gandhasaale	8.57 ^{ghi}	11.23 ^{b}	2.53 ^{cde}	1.60 ^{h}	1.46 ^{bcde}	74.61 ^{f}	366.17 ^{ab}
	20	Kalajeera	8.82 ^{fghi}	8.28 ^{i}	2.45 ^{cdef}	1.58 ^{h}	1.45 ^{bcde}	77.44 ^{a}	364.86 ^{abc}
	F test		6.805	49.93	4.001	282.53	6.283	16.515	24.715
	P value		1.9E-07	5.56E-22	0.00011	1.27E-36	5.48E-07	2.49E-13	2.3E-16
	SEm±		0.173	0.168	0.125	0.033	0.046	0.310	0.796
	CD at 5%		0.480	0.466	0.348	0.091	0.127	0.860	2.206

* Significant at 5% level

Note: #Carbohydrate by difference

Means in the same column followed by different superscript letters differ significantly

Mean proximate composition in comparison with IR 64 rice (per 100 g) (control)

Table 2 depicts the mean proximate composition of traditional rice varieties in comparison with IR 64 rice values[22]. Overall, the mean protein (9.04 g), fat (2.52 g), ash (1.43 g), and carbohydrate (75.73 g) values of traditional rice varieties were reported higher compared to the IR 64 rice values, whereas the mean moisture (13.60 g), fibre (4.96 g) and energy (396.75 Kcal) values were higher in IR 64 rice (control). With regard to grain type, similar trend was observed as in overall mean proximate composition of traditional rice varieties.

Babu *et al.* reported that, brown rice is superior to polished rice in terms of nutrients and health benefits[36]. In their study, they compared brown rice with white rice and data was adopted from USDA National nutrient database for standard reference [5]. They have also reported higher protein (4.88 g/100g) and fat (1.17 g/100g) content in brown rice compared to white rice.

According to IRRI, rice bran contains a substantial amount of fibre compared with other parts of the rice grain[13]. Therefore, the consumption of milled rice could result in a diet low not only in dietary fibre but also in essential fatty acids. It has been shown that 13.7 per cent of protein, 50.0 per cent of ash, 61.5 per cent of fat, and 68.4 per cent of fibre are removed from brown rice in the polishing process [37]. Today, the consumers prefer to eat unpolished rice especially traditional rice because of its health benefits. Therefore the demand for brown rice is increasing among the population [38].

Mineral composition

Minerals are essential for normal metabolic functions and are required components in balanced diet. Traditional rice varieties are excellent source of minerals as shown in Table 3. Table 4 depicts the mineral composition of traditional rice varieties in comparison with IR 64 rice values [22, 39]. The results are expressed in terms of mg per 100g.

Among the micro and macro minerals, iron content ranged from 1.34 to 3.36 mg, zinc from 2.22 to 3.72 mg, calcium from 18.32 to 24.07 mg and phosphorus from 225.25 to 248.41 mg per 100 g. Deepa *et al.* reported significantly higher iron (1.93 mg/100g), calcium (11.6 mg/100g) and phosphorus (354.0 mg/100g) content in Indian medicinal rice Njavara to non medicinal rice varieties Jyothi and IR 64 [22]. In the present study, iron content was within the range, whereas slightly higher values for calcium and lower values for phosphorus were recorded. Zinc content reported by Liang *et al.* was 2.03 mg/100g in short grain, 2.28 mg/100 g in medium grain and 2.46 mg/100 g in long grains [40]. These findings are in agreement with the findings of present study. The differences in mineral composition of rice varieties may be affected by their growing environments and genetic differences [41].

Table 2: Mean proximate of traditional rice varieties in comparison with IR 64 rice (per 100g)

Proximates (g)	IR 64 (g)	Grain type	Mean ± SD	Overall (Mean ± SD)
A. Moisture	13.60	Long	9.16 ± 0.46	8.98 ± 0.45
		Medium	8.89 ± 0.50	
		Short	8.82 ± 0.28	
B. Protein	7.95	Long	8.77 ± 0.79	9.04 ± 1.19
		Medium	9.01 ± 1.42	
		Short	9.65 ± 1.43	
C. Fat	2.06	Long	2.41 ± 0.19	2.52 ± 0.25
		Medium	2.52 ± 0.21	
		Short	2.71 ± 0.36	
D. Fibre	4.96	Long	2.42 ± 0.62	2.30 ± 0.55
		Medium	2.37 ± 0.52	
		Short	1.93 ± 0.39	
E. Ash	1.27	Long	1.45 ± 0.06	1.43 ± 0.11
		Medium	1.39 ± 0.15	
		Short	1.51 ± 0.09	
F. Carbohydrate[#]	74.10	Long	75.81 ± 0.70	75.73 ± 1.26
		Medium	75.82 ± 1.65	
		Short	75.40 ± 1.55	
G. Energy (Kcal)	396.75	Long	360.00 ± 3.74	361.72 ± 3.96
		Medium	362.04 ± 4.22	
		Short	364.51 ± 2.50	

Note: IR 64 values are taken from Deepa *et al.* (2008) [#]Carbohydrate calculated by difference

Table 3: Mineral composition (mg/100g) of traditional rice varieties

Category	No.	Varieties	Iron	Zinc	Calcium	Phosphorus
Long grain	1	Gamnad batta	2.25 ef	2.44 fghi	20.40 e	232.56 h
	2	Anandi	1.44 h	2.52 efghi	20.58 e	229.08 k
	3	Krishnaleela	3.25 a	3.33 ab	18.32 g	225.39 n
	4	Kagisaale	2.13 f	2.92 bcde	19.42 f	229.08 k
	5	Murakan sanna	2.49 de	2.29 i	22.58 b	236.35 f
	6	Mysore mallige	2.55 cd	2.22 i	20.19 e	225.45 n
	7	Nagabatta	2.10 f	2.31 ghi	21.46 d	235.50 g
	8	Gajagunda	3.26 a	3.31 ab	22.16 bc	231.79 i
Medium grain	9	Doddabyranellu	3.36 a	3.18 bcd	21.86 cd	236.62 e
	10	Ratnachoodi	2.79 bc	2.75 defg	20.50 e	225.25 n
	11	Malgudi sanna	2.79 bc	2.35 ghi	20.49 e	238.42 c
	12	Gowrisanna	2.64 bcd	2.36 fghi	19.40 f	227.88 l
	13	Chinna ponni	1.34 h	2.31 hi	20.69 e	225.75 m
	14	Salem sanna	2.08 f	2.38 fghi	19.56 f	238.02 d
	15	Karimundaga	2.88 b	3.72 a	20.20 e	232.74 h
	16	Rajmudi	2.53 cde	2.49 efghi	22.63 b	232.48 h
Short grain	17	Rajakaime	1.76 g	2.53 efghi	24.07 a	248.41 a
	18	Jeerige sanna	2.11 f	2.74 defgh	23.85 a	241.91 b
	19	Gandhasaale	2.15 f	2.79 cdef	20.26 e	230.98 j
	20	Kalajeera	2.21 f	3.19 bc	20.37 e	231.79 i
		F test	30.077	7.519	67.315	646.89
		P value	6.72E-18	4.89E-8	1.9E-24	9.13E-44
		SEm±	0.102	0.158	0.183	0.237
		CD at 5%	0.282	0.438	0.506	0.658

* Significant at 5% level

Note: Means in the same column followed by different superscript letters differ significantly

Mean mineral composition in comparison with IR 64 rice (per 100 g)

Table 4 depicts the mean mineral composition of traditional rice varieties in comparison with IR 64 rice values. Overall, the mean calcium (20.95 mg) and zinc (2.71 mg) content of traditional rice varieties were reported higher compared to the IR 64 rice values (9.20 g and 1.60 mg respectively). Whereas mean iron (2.73 mg) and phosphorus (301 mg) values of IR 64 was higher compared to traditional rice varieties. With regard to grain type, similar trend was observed as in overall mean mineral composition of traditional rice varieties in comparison with IR 64 rice.

Babu *et al.* recorded significantly higher phosphorus (142 mg) and zinc (1.05 mg) content in brown rice compared to white rice [36]. The data for brown and white rice were taken from USDA National nutrient database for standard reference.

Total sugars, reducing and non reducing sugars

Statistical significant differences were observed between the rice varieties and the results are expressed in terms of g per 100g for total sugars, reducing and non reducing sugar (Table 5). Overall, total sugars and reducing sugars found significantly lowest in Gajagunda (0.42 g & 0.27 g) and highest in Jeerige sanna (0.92 g & 0.65 g). Whereas, Gandhasaale (0.29 g) and Kalajeera (0.29 g) recorded highest non reducing sugars and lowest was observed in Salem sanna (0.12 g). The total sugar content of traditional rice varieties in the present correspond to that reported by Moongngarm and Saetung, who reported the total sugar content of 0.91 per cent in ungerminated waxy rice cultivar from Thailand[42].

The composition of reducing sugar and total sugars is due to the starch degradation presumably being involved in the initial action of α-amylase on the starch granules. The other hydrolyses probably assisted in the complete hydrolysis to simple sugar and reducing sugar, such
as the action of invertase, which hydrolysis sucrose to glucose and fructose [42].

Table 4: Mean mineral composition (per 100g) of traditional rice varieties in comparison with IR 64 rice

Minerals (mg)	IR 64 (mg)	Grain type	Mean ± SD	Overall (Mean ± SD)
A. Iron	2.73	Long	2.43 ± 0.61	2.41 ± 0.56
		Medium	2.55 ± 0.61	
		Short	2.06 ± 0.20	
B. Zinc	1.60	Long	2.67 ± 0.46	2.71 ± 0.43
		Medium	2.69 ± 0.51	
		Short	2.81 ± 0.28	
C. Calcium	9.20	Long	20.64 ± 1.41	20.95 ± 1.50
		Medium	20.67 ± 1.09	
		Short	22.14 ± 2.11	
D. Phosphorus	301.00	Long	230.65 ± 4.15	232.77 ± 6.04
		Medium	232.15 ± 5.36	
		Short	238.27 ± 8.39	

Note: IR 64 values are taken from Deepa *et al.* (2008) and Jeng *et al.* (2012)

Table 5: Total sugars, reducing and non reducing sugars (g/100g) of traditional rice varieties

Category	No.	Varieties	Total sugars	Reducing sugars	Non reducing sugars
Long grain	1	Gamnad batta	0.55^{h}	0.37^{e}	0.18^{defg}
	2	Anandi	0.88^{ab}	0.62^{ab}	0.26^{ab}
	3	Krishnaleela	0.85^{abc}	0.65^{a}	0.20^{cdef}
	4	Kagisaale	0.84^{bc}	0.63^{ab}	0.21^{bcde}
	5	Murakan sanna	0.54^{h}	0.32^{ef}	0.22^{bcd}
	6	Mysore mallige	0.82^{bcd}	0.57^{abc}	0.25^{abc}
	7	Nagabatta	0.66^{fg}	0.48^{cd}	0.18^{defg}
	8	Gajagunda	0.42^{j}	0.27^{f}	0.15^{gh}
Medium grain	9	Doddabyranellu	0.50^{hi}	0.31^{ef}	0.19^{defg}
	10	Ratnachoodi	0.72^{ef}	0.54^{bcd}	0.18^{defg}
	11	Malgudi sanna	0.77^{cde}	0.61^{ab}	0.16^{fgh}
	12	Gowrisanna	0.87^{ab}	0.60^{ab}	0.26^{ab}
	13	Chinna ponni	0.82^{bcd}	0.61^{ab}	0.21^{bcde}
	14	Salem sanna	0.43^{ij}	0.30^{ef}	0.12^{h}
	15	Karimundaga	0.52^{h}	0.37^{e}	0.15^{fgh}
	16	Rajmudi	0.64^{g}	0.47^{d}	0.17^{efgh}
Short grain	17	Rajakaime	0.76^{de}	0.60^{ab}	0.16^{fgh}
	18	Jeerige sanna	0.92^{a}	0.65^{a}	0.27^{a}
	19	Gandhasaale	0.86^{ab}	0.57^{abc}	0.29^{a}
	20	Kalajeera	0.89^{ab}	0.60^{ab}	0.29^{a}
	F test		34.30	9.882	13.202
	P value		6.09E-19	9.29E-10	1E-11
	SEm±		0.028	0.036	0.016
	CD at 5%		0.079	0.101	0.045

* Significant at 5% level

Note: Means in the same column followed by different superscript letters differ significantly

Dietary fibre fractions

Dietary fibre is gaining importance due to its beneficial effects on health. The consumption of whole grains is an actual tendency in healthy nutrition [43]. The dietary fibre fractions of traditional rice differed significantly between the varieties (Table 6). According to IRRI, rice bran contains a substantial amount of fibre compared with other parts of the rice grain[13].

Insoluble dietary fibre (per 100g)

Insoluble dietary fiber does not dissolve in water, is metabolically inert and provides bulking or it can be prebiotic and metabolically ferment in the large intestine. For all the traditional rice varieties tested, IDF accounted for the great majority of total dietary fibre and it varied between 4.34 and 9.79 g per 100 g. The findings were within the range reported by Lu *et al.* and recorded IDF between 3.6 to 6.8 per cent and 4.5 to 8.1 in Taiwanese brown rice [44].

Soluble dietary fibre (per 100g)

Soluble dietary fiber (SDF), which dissolves in water, is readily fermented in the colon into gases and physiologically active byproducts, and can be prebiotic and viscous[45]. Irrespective of grain type, Malgudi sanna (0.62 g) and Kagisaale (0.61 g) recorded highest SDF content and least was recorded by Gandhasaale (0.12 g). The values were within the range reported by Deepa *et al.* in Indian medicinal rice Njavara and non medicinal rice varieties, Jyoti and IR 64 [22].

Total dietary fibre (per 100g)

Dietary fiber or roughage is the indigestible portion of food derived from plants. The amount of total dietary fibre (TDF) ranged between 4.46 to 10.40 g among all the rice varieties. Irrespective of grain type, long grain variety Kagisaale (10.40 g) recorded highest TDF while, short grain variety Gandhasaale (4.46 g) recorded least. The results for TDF obtained in this study were similar to the values reported by Deepa *et al.* and Lu *et al.* [22, 44].

Table 6: Dietary fibre fractions of traditional rice varieties

Category	No.	Varieties	Dietary fibre (g/100g)		
			Insoluble	Soluble	Total
Long grain	1	Gamnad batta	5.30 m	0.16 no	5.45 n
	2	Anandi	6.15 k	0.23 kl	6.38 l
	3	Krishnaleela	8.41 d	0.44 c	8.85 e
	4	Kagisaale	9.79 a	0.61 a	10.40 a
	5	Murakan sanna	7.97 e	0.43 cd	8.40 f
	6	Mysore mallige	8.89 c	0.54 b	9.42 d
	7	Nagabatta	5.74 l	0.20 lm	5.94 m
	8	Gajagunda	9.54 b	0.42 cde	9.96 c
Medium grain	9	Doddabyranellu	9.56 b	0.43 cd	9.99 c
	10	Ratnachoodi	7.16 h	0.33 gh	7.49 i
	11	Malgudi sanna	9.63 b	0.62 a	10.25 b
	12	Gowrisanna	7.30 g	0.38 ef	7.68 gh
	13	Chinna ponni	7.46 f	0.35 fg	7.81 g
	14	Salem sanna	7.29 g	0.29 hi	7.59 hi
	15	Karimundaga	8.41 d	0.40 de	8.81 e
	16	Rajmudi	6.76 i	0.27 ij	7.04 j
Short grain	17	Rajakaime	6.44 j	0.24 jk	6.68 k
	18	Jeerige sanna	8.88 c	0.50 b	9.38 d
	19	Gandhasaale	4.34 n	0.12 o	4.46 o
	20	Kalajeera	5.79 l	0.18 mn	5.97 m
	F test		1344.99	127.12	1388.80
	P value		4.2E-50	8.5E-30	2.22E-50
	SEm±		0.043	0.013	0.047
	CD at 5%		0.121	0.036	0.129

* Significant at 5% level

Note: Means in the same column followed by different superscript letters differ significantly

Mean dietary fibre fractions in comparison with IR 64 rice (per 100 g)

Table 7 depicts the mean dietary fibre fractions of traditional rice varieties in comparison with IR 64 rice values. Overall, the mean insoluble (7.54 g) and total dietary fibre (7.90 g) content of traditional rice varieties were reported higher compared to the IR 64 rice values, whereas the mean soluble dietary fibre content found lower. With regard to grain type, similar trend was observed as in overall mean dietary fibre fractions of traditional rice varieties in comparison with IR 64 rice. Comparison of nutrient contents of brown rice and white rice was reported by Babu *et al.* and showed that, brown rice contained more dietary fibre (3.32 g) than white rice (0.74 g) [36]. Hence minimal polishing will preserve the TDF a phytonutrient and provide functional benefits.

Total starch, amylose, and amylopectin

Rice starch is one of the key ingredients of various food products[46]. In the culinary characteristics, starch is important due to nutritional importance of polysaccharide [43]. Total starch, amylose and amylopectin content of traditional rice varieties were depicted in Table 8. Results were expressed in terms of per cent.

Total starch

Starch is the major component of rice constituting about 90 per cent of its dry matter [47]. There are two main polymers in rice starch granules, i.e. amylose and amylopectin [48]. In the present study, total starch markedly varied among all the rice varieties ranging from 68.31 (Doddabyranellu) to 76.14 (Kagisaale) per cent. Similar findings were reported by Yadav *et al.* for total starch content ranging from 68.73 to 70.24 per cent in four non-basmati and two basmati Indian rice cultivars [49].

Amylose

Amylose is a helical polymer made of α-D-glucose units, bound to each other through α(1→4) glycosidic bonds. This polysaccharide is one of the two components of starch, making up approximately 20 to 30 per cent of the structure. Amylose is one of the most important determinants of rice quality and acceptability by consumer. Significant difference for amylase content was reported. In the present study it ranged from 11.20 (Nagabatta) to 24.64 (Jeerige sanna) per cent in traditional rice varieties (Fig. 1). The amylose content in rice grains varied with the climatic and soil conditions during grain development [50-52]. Amylose content of brown rice flours from *Indica* and *Japonica* cultivars reported by Morales-Martinez ranged from 5.63 to 24.59 per cent. In the present study, amylose values fall within this range [43].

Table 7: Mean dietary fibre (per 100g) fractions of traditional rice varieties in comparison with IR 64

Dietary fibre (g)	IR 64 (g)	Grain type	Mean ± SD	Overall (Mean ± SD)
A. Insoluble	4.43	Long	7.72 ± 1.76	7.54 ± 1.60
		Medium	7.95 ± 1.12	
		Short	6.36 ± 1.89	
B. Soluble	0.53	Long	0.38 ± 0.16	0.36 ± 0.15
		Medium	0.38 ± 0.11	
		Short	0.26 ± 0.17	
C. Total	4.96	Long	8.10 ± 1.92	7.90 ± 1.73
		Medium	8.33 ± 1.21	
		Short	6.62 ± 2.06	

Note: Standard values are taken from Deepa *et al.*, (2008)

Amylopectin

The other component of rice starch is amylopectin, a soluble polysaccharide which makes up 70 to 80 per cent of the structure, composed of glucose molecules with branched links [α(1→4), α(1→6)] . With regard to amylopectin content, it ranged from 46.82 in Jeerige sanna up to 60.98 per cent in Nagabatta among all the traditional rice varieties. The amylopectin values are comparable with the values reported by Oko *et al.* [53]

Table 8: Starch, amylose and amylopectin content of traditional rice varieties

Category	No.	Varieties	Total starch (%)	Amylose (%)	Amylopectin (%)	Amylose/ Amylopectin ratio
Long grain	1	Gamnad batta	73.83 ^{ef}	20.38 ^{e}	53.46 ^{g}	0.37 ^{e}
	2	Anandi	70.87 ^{j}	12.82 ^{m}	58.04 ^{c}	0.22 ^{m}
	3	Krishnaleela	68.76 ^{k}	21.68 ^{c}	47.08 ^{i}	0.45 ^{b}
	4	Kagisaale	76.14 ^{a}	22.67 ^{b}	53.47 ^{g}	0.42 ^{c}
	5	Murakan sanna	69.06 ^{k}	14.07 ^{l}	54.99 ^{e}	0.26 ^{l}
	6	Mysore mallige	70.87 ^{j}	17.07 ^{hi}	53.80 ^{fg}	0.32 ^{hi}
	7	Nagabatta	72.18 ^{hi}	11.20 ^{n}	60.98 ^{a}	0.18 ^{n}
	8	Gajagunda	75.12 ^{bc}	16.60 ^{ij}	58.52 ^{c}	0.28 ^{j}
Medium grain	9	Doddabyranellu	68.31 ^{k}	16.04 ^{j}	52.27 ^{h}	0.30 ^{i}
	10	Ratnachoodi	73.91 ^{ef}	18.55 ^{f}	55.36 ^{e}	0.33 ^{g}
	11	Malgudi sanna	74.42 ^{cde}	21.12 ^{cd}	53.30 ^{g}	0.41 ^{d}
	12	Gowrisanna	69.08 ^{k}	17.34 ^{gh}	51.74 ^{h}	0.34 ^{g}
	13	Chinna ponni	72.42 ^{gh}	12.51 ^{m}	59.90 ^{b}	0.21 ^{m}
	14	Salem sanna	70.91 ^{j}	17.41 ^{gh}	53.49 ^{g}	0.31 ^{gh}
	15	Karimundaga	74.17 ^{de}	17.84 ^{g}	56.33 ^{d}	0.32 ^{hi}
	16	Rajmudi	75.64 ^{ab}	21.06 ^{d}	54.58 ^{ef}	0.39 ^{de}
Short grain	17	Rajakaime	75.00 ^{bcd}	16.18 ^{j}	58.82 ^{c}	0.27 ^{jk}
	18	Jeerige sanna	71.46 ^{ij}	24.64 ^{a}	46.82 ^{i}	0.54 ^{a}
	19	Gandhasaale	70.90 ^{j}	18.79 ^{f}	52.11 ^{h}	0.36 ^{f}
	20	Kalajeera	73.08 ^{fg}	15.09 ^{k}	57.99 ^{c}	0.26 ^{kl}
	F test		65.72	317.33	120.95	273.57
	P value		3.01E-24	1.28E-37	2.26E-29	2.41E-36
	SEm±		0.301	0.200	0.344	0.005
	CD at 5%		0.833	0.554	0.954	0.014

* Significant at 5% level

Note: Means in the same column followed by different superscript letters differ significantly

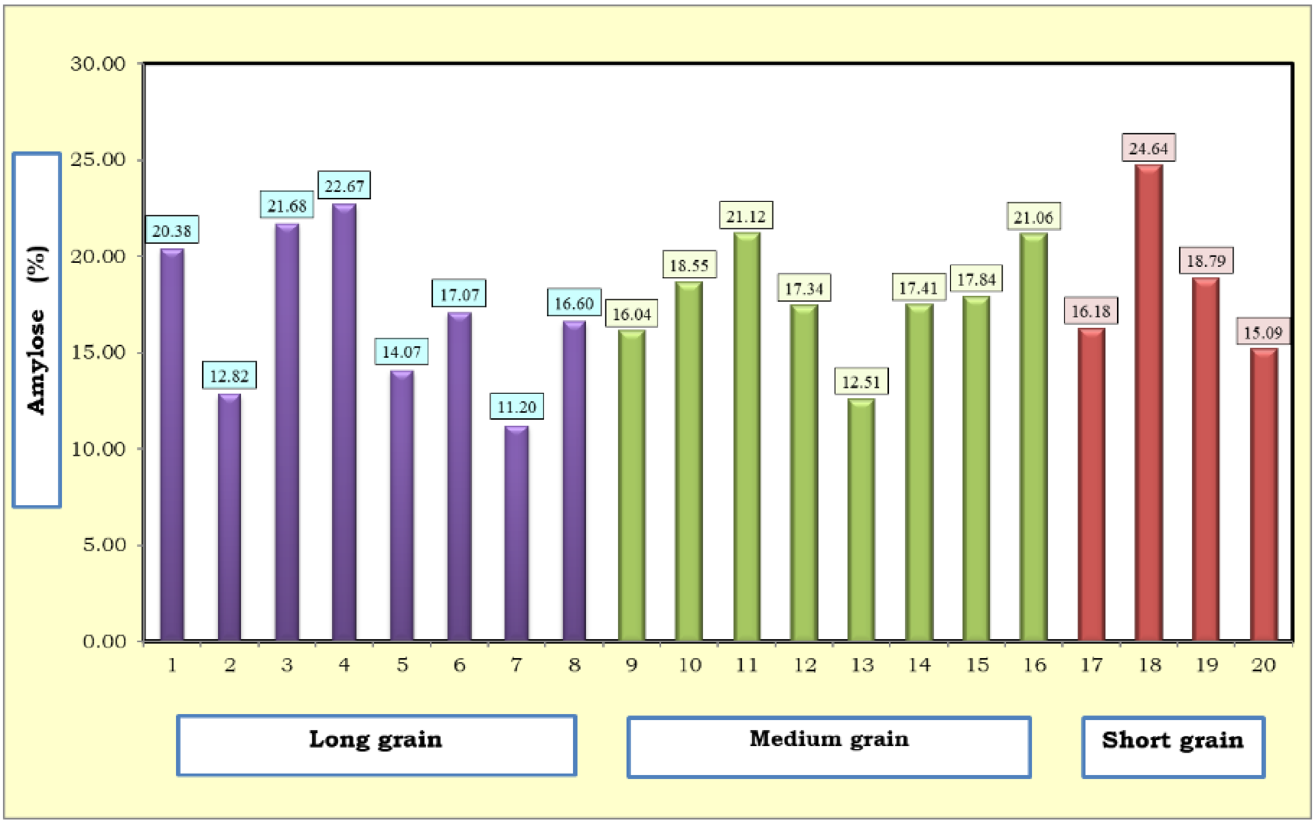

Fig 1: Amylose content of traditional rice varieties

Amylose to amylopectin ratio

The amylose to amylopectin ratio and their structures greatly influence the physico-chemical, thermal, functional, and rheological properties of starch. Behall *et al.* reported that, the ratio of amylose to amylopectin in starch has an impact on the glycemic response to starch based foods [54]. Irrespective of grain classification, amylose to amylopectin ratio was found significantly highest in Jeerige sanna (0.54) followed by Krishnaleela (0.45) and then Kagisaale (0.42) and least was observed in Nagabatta (0.18). The amylose to amylopectin ratio appears to be correlated with high amounts of resistant starch (RS) as mentioned in literature [55, 56].

Amylose classification

The proportion of amylose in the starch is predominantly responsible for the different physico-chemical and cooking properties of the rice kernel and rice has been categorised into high amylose, intermediate amylose, low amylose and waxy rice types [57, 58]. In this study, based on amylose, rice varieties were classified in to low (12-20%) and intermediate (20-25%) and results are presented in Table 9. About fourteen (70%) rice varieties were classified under low amylose and six (30.0%) under intermediate amylose. Chavez-Murillo *et al.* classified Mexican rice cultivars based on amylose and showed that six cultivars have high amylose content, and three cultivars have intermediate amylose content [30]. Rice with intermediate amylose content (20-25%) has been reported to cook moist and remain soft (when cool) and is widely preferred than rice with high (20-25%) or low amylose contents (10-20%).

Table 9: Amylose classification of traditional rice varieties

Amylose classification	Varieties		Amylose (%)
	N	%	Mean ± SD
Low (12-20%)	14	70.0	17.97 ± 3.75
Intermediate (20-25%)	6	30.0	21.93 ± 1.54
Total	20	100.0	

Conclusion

The results of this study demonstrated a wide range of nutritional properties among traditional rice varieties, which provided the basic information for future development of food applications using these varieties. Thus traditional rice varieties are good source of minerals, dietary fibre, and protein. This is the first documentation on chemical and nutrient content of traditional rice varieties with grain type and grain size. Although there are some differences found between control (IR 64) and tested varieties, the present study documented polishing and milling results in loss of nutrients. Hence brown rice from traditional rice varieties with minimal polishing is better.

Thus traditional rice has very good chemical and nutrient composition when compared to commonly used rice sample. The consumption of these rice varieties should be promoted to avail the nutritional benefits especially among people with non communicable diseases and vulnerable sections of the society. As traditional rice varieties are better source of protein and dietary fibre and other nutritional properties provide useful basic information for future developments of food applications using these varieties. The data in this work would increase both domestic and industrial utilization of these varieties and thereby enhance the production of the traditional rice varieties.

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