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Nutrient composition and physicochemical properties of Indian medicinal rice – Njavara

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Abstract

Njavara, a medicinal rice, was assessed for its nutrient composition and physicochemical properties, in order to understand its therapeutic properties. Dehusked Njavara rice consisted of 73% carbohydrates, 9.5% protein, 2.5% fat, 1.4% ash and 1628 kJ per 100 g of energy. Physicochemical properties and nutritive components of dehusked rice of Njavara were evaluated and compared with two commonly consumed non-medicinal rice varieties – Jyothi (red coloured) and IR 64 (brown coloured). The carbohydrates, fats, apparent amylose equivalent, fatty acid profile and triglycerides of Njavara were comparable to Jyothi and IR 64. However, Njavara rice had 16.5% higher protein, and contained higher amounts of thiamine (27–32%), riboflavin (4–25%) and niacin (2–36%) compared to the other two rice varieties. The total dietary fibre content in Njavara was found to be 34–44% higher than that of Jyothi and IR 64. Significantly higher phosphorus, potassium, magnesium, sodium and calcium levels were found in Njavara rice, compared to the other two varieties. The cooking time of dehusked Jyothi and IR 64 varieties were found to be 30 min, while Njavara needed longer time to cook, (38 min). The cooked rice of Njavara was slimy in nature, probably due to the presence of non-starch polysaccharides.

Keywords: Njavara; Medicinal rice; Physicochemical properties; Amylose

1. Introduction

Rice is one of the most important cereals and commercially more than two thousand varieties of rice are grown throughout the world. It is the staple food of more than three billion people, mainly in Asia. The Ayurvedic Treatise (Indian Materia Medica) records show the existence of many medicinal rice varieties in India (Das & Oudhia, 2003). Thus, proper documentation and research data on these varieties is of great importance. Njavara belongs to the family *Oryza*. It is believed to be a progenitor of Asiatic rice with an unadulterated gene pool (Nair & Thomas, 2001). It is a wild variety of rice grown exclusively in Kerala, South India, since ancient times, and is used mainly for ayurvedic treatments. Njavara is an upland crop and cultivated in a water-stressed environment (Menon, 2004). Njavara paddy has low yield and is found to be moderately resistant to pests. The dehusked rice is red in colour. In southern United States, Greece, Latin America, Spain and other temperate regions, red rice is considered a weed, which grows along with cultivated rice (Patindol, Flowers, Kuo, Wang, & Gealy, 2006). However, in Bhutan, China, India, Sri Lanka, Philippines, red rice is grown as a staple rice cultivar (Itani & Ogawa, 2004; Srinivas, 1976). Red rice is gaining popularity in Japan as a functional food because of its high polyphenols and anthocyanin content (Itani & Ogawa, 2004; Ling, Cheng, Ma, & Wang, 2001; Perera & Jansz, 2000).

Morphologically, Njavara is similar to ordinary rice, with husk colour varying from golden yellow to brownish black, depending upon the edaphic and climatic conditions (Menon, 2004). This rice is grown in semi-dry conditions; it takes about 60 days to mature and is referred to locally as

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"sastika" variety of rice. Njavara is at the brink of extinction due to low yields, high cost and its present use, which is limited to ayurvedic preparations/treatments only. Njavara is regarded as a special rice variety with beneficial properties for the circulatory, respiratory and digestive systems, according to the Indian indigenous system of medicine or Ayurveda. It is bestowed with many medicinal properties and is used for the treatment of arthritis, cervical spondylitis, muscle wasting, skin diseases and certain neurological problems. The medicinal quality of the rice is preserved by using only dehusked rice. Njavara kizhi is a specialised Ayurvedic therapy for treatment of paralysis, arthritis and neurological problems. In this therapy, a poultice is prepared by cooking Njavara rice in milk, with certain herbs, like *Sida rectusa* and *Alpinia galanga* and used for topical massage of the entire body. This treatment leads to heat generation, extensive perspiration of the body, increase in blood circulation and relieves stiffness of the joints and arthritic pain. However, no scientific data are available on the nutritional and medicinal properties of Njavara. The present study investigates the nutritional properties of Njavara, in comparison with non-medicinal rice varieties Jyothi (a red variety) and IR 64 (a normal variety).

2. Materials and methods

2.1. Materials

Njavara paddy was brought from Padma Ayurveda, Mannar (Kerala), while Jyothi and IR 64 paddy were procured from Agriculture Products Marketing Cooperative in Mysore. Paddy harvested in December 2003 was obtained and stored at room temperature for one year and five months and then stored at 4–6 °C until use. All chemicals used were of analytical grade (Merck), unless stated otherwise. Potato amylose was obtained from ICN Biochemicals, USA. Esters of fatty acids, viz., oleic acid, stearic acid, palmitic acid, linolenic acid, linoleic acid, and USP grade standards of vitamins, namely niacin, folic acid, riboflavin and thiamine, were procured from Sigma Chemical Company, USA. The standards for minerals were procured from Merck, India.

2.2. Methods

The paddy samples were dehusked using a rubber roller dehusker (Satake Corporation, Tokyo, Japan). Cooking times of dehusked rice were determined according to the method of Desikachar and Subrahmanyan (1961), and Ranghino (1966). The rice grains were cooked in excess water and pressed between two glass slides. The cooking time was recorded until the white core of the grain disappeared. The grains were powdered in a Surabhi rice mill and the flour was passed through a 60-mesh sieve. The flour was defatted using a Soxhlet apparatus for 18–20 h with 85% methanol, placed in ambient conditions to equilibrate moisture content (12–13%) and then stored at 4 °C until used for amylose estimation.

2.3. Amylose content/equivalent

Amylose from defatted brown rice flour was estimated using the method of Sowbhagya and Bhattacharya (1979). Total amylose equivalent, soluble amylose and insoluble amylose equivalent were derived. Potato amylose was used as a standard.

2.4. Proximate analysis

The moisture content of the rice flour was determined after drying at 105 °C until a constant weight was attained (Induhara Swamy, Ali, & Bhattarcharya, 1971). The micro-Kjeldahl method was employed to determine the total nitrogen and the crude protein ($N \times 5.95$) (AOAC, 2000). Crude lipids were extracted with hexane, using a Soxhlet apparatus and ash contents (gravimetric) were determined based on methods outlined in AOAC (2000). The total crude carbohydrate was estimated by the phenol-sulfuric acid method (Dubois, Gilles, Hamilton, Rebers, & Smith, 1956). Dietary fibre was estimated using the method of Englyst and Hudson (1996). Gross energy was calculated based on the formula (Ekanayake, Jansz, & Nair, 1999):

$$\text{gross energy (kJ per 100 g dry matter)} \\ = (\text{crude protein} \times 16.7) + (\text{crude lipid} \times 37.7) \\ + (\text{crude carbohydrates} \times 16.7).$$

2.5. Scanning electron microscopy (SEM)

Scanning electron micrographs of the native and cooked brown rice flour were obtained with a scanning electron microscope (LEO 435VP, LEO Electron Microscopy Ltd., Cambridge, Electron). The flour was mounted on round aluminum stubs with the aid of double-sided adhesive tape. The samples were coated with gold (~100 μm) by means of a KSE 24M high vacuum evaporator and scanned. The selected regions were photographed.

2.6. Mineral analysis

Levels of sodium, potassium, calcium, magnesium and iron in the brown rice flour samples were determined by atomic absorption spectrophotometry (Perkin–Elmer, Analysist A 700) after digestion with concentrated nitric acid (AOAC, 2000). Total phosphorus was determined spectrophotometrically at 355 nm using KH_2PO_4 as a standard (Singh & Ali, 1987).

2.7. Fatty acid analysis

Lipids were extracted from brown rice flour by Soxhlet apparatus for 8 h using hexane. The extracts were concentrated and stored at 4 °C, until use. Aliquots of the lipid extracts of Njavara, Jyothi and IR 64 were converted to fatty acid methyl esters, using methanol and boron triflouride (Morrison & Smith, 1964). The fatty acid methyl esters were analysed by gas chromatography with flame ionisation detector, using a BP21 column (SGE, Ringwood, Australia). The conditions of the analysis were: injector temperature 220 °C, detector temperature 230 °C and column temperature 180 °C and nitrogen carrier gas at a flow rate of 1.0 ml per min. Identification of fatty acids was based on the retention times of methyl esters of standard fatty acids.

2.8. Triglyceride analysis

High performance liquid chromatography was used for analysis of triglycerides in oil samples of brown rice flour (Bland, Conkerton, & Abraham, 1991). Aliquots of oil samples dissolved in acetone were chromatographed on a Supelcosil C_{18} ($250 \times 4.6\ mm^2$, 5.0 μm particle size; Supelco Bellefonte, PA) column, using acetone: acetonitrile (55:45 v/v) as mobile phase. Elution was carried out isocratically at a column temperature of 30 °C and a flow rate of 0.8 ml per min. An RI detector, held at a constant temperature of 40 °C was used. Identification of triglyceride molecular species (TGMS) was achieved on the basis of retention time and the percentage area of triglycerides.

2.9. Statistical analysis

The statistical significance of the data was analyzed using the paired student's *t*-test method. Significant differences between the means of Njavara and Jyothi, Njavara and IR 64 were presented at $P < 0.05$.

3. Results and discussion

The agronomical characteristics of Njavara and non-medicinal varieties are presented in Table 1. Njavara is a red-coloured, wild variety of rice with a progenitor of Asiatic rice and an unadulterated gene pool (Nair & Thomas, 2001). Njavara rice is not consumed as a staple variety, as it is expensive, compared to commonly consumed hybrid rice varieties. Hence, Njavara is used exclusively in local traditional ayurvedic preparations. Njavara is grown in semi-arid conditions and needs about 60 days for maturity. Jyothi is a hybrid variety (PTB 39) with a parentage of PTB 10 × IR 8. The dehusked rice is red in colour, similar to Njavara, but it is consumed as a staple food in Kerala. IR 64 is a high yielding, hybrid, non-pigmented variety with a parentage of IR 5657 × IR 2061. Both Jyothi and IR 64 varieties need 90–120 days to mature.

Grain colour, size and shape are considered as important criteria for understanding the physical properties of rice. Dehusked rice of Njavara and Jyothi are red-pigmented while IR 64 is brownish in colour. Table 2 shows some of the physical properties of these three rice varieties. The shelling turnovers of Njavara, Jyothi and IR 64 were found to be about 80%. The husk and the endosperm were of the same colour, in the case of Njavara and Jyothi. Based on the (length/breadth) ratio, Njavara and Jyothi could be classified as long and bold varieties, while IR 64 is a long and slender variety (Table 2).

The cooking time is generally higher in brown rice, compared to milled or polished rice, because of a thick aleurone layer and a pericarp which delay water penetration into the grains during cooking. Progressive cooking of brown rice leads to opening of kernels along the dorsal and ventral lines of fusion (Mahadevappa & Desikachar, 1968). Stienbarger (1932) reported a cooking time of 16–23 min in eight

Table 1
Agronomical features of Njavara and other rice varieties

Popular name	Variety/origin	Crop maturation (days)	Parentage	Agronomical features
Njavara	Wild, Kerala	60–90	Progenator of Asiatic rice	Low yield, moderately tolerant to pests.
PTB 39/ Jyothi	Hybrid RARS, Pattambi, Kerala	110–115	PTB 10 × IR 8	Susceptible to sheath blight, moderately tolerant to BPH and blast, excessive shedding of grains at maturity.
IR 64	Hybrid IRRI, Philippines	90–120	IR5657 × IR2061	Released in 1992 in India. High yielding variety, used as a recurrent parent in many breeding programmes.

Table 2
Physical characteristics of Njavara and other rice varieties

Variety	Shelling turnover (%)	Appearance	Length (mm)	Breadth (mm)	l/b[a]	Cooking time (min)
Njavara	79.79 ± 1.35	Red, long, bold	6.63 ± 0.03	2.44 ± 0.07	2.72 ± 0.07	38 ± 0.5
Jyothi	78.95 ± 0.86	Red, long, bold	6.69 ± 0.07	2.52 ± 0.08	2.65 ± 0.09	30 ± 0.5
IR 64	78.87 ± 1.23	Brownish white long, slender	6.93 ± 0.05	2.13 ± 0.03	3.26 ± 0.05	30 ± 0.25

Values are mean ± standard error of four determinations.
[a] Length/breadth ratio.

varieties of polished rice. The dehusked rice of Jyothi and IR 64 needed 30 min for cooking and the cooked grains were slender and flaky due to high amylose content. However, Njavara dehusked grains needed a longer period of 38 min to cook (Table 2); the cooked grains were also flaky but were slimy in nature, even though its amylose content was high. This property could be due the presence of non-starch polysaccharides (NSP). The longer cooking time of Njavara compared to the other two rice varieties could be due to thicker pericarp, aleurone layer and also NSP in the dehusked rice. Further, the pasting and thermal properties of dehusked Njavara rice were found to be very different from those of Jyothi and IR 64 (unpublished data).

Amylose content is one of the most important determinants of rice quality. Rice contains both soluble and insoluble amylose. Insoluble amylose of rice directly affects kernel firmness and inversely affects stickiness and glossiness of cooked grain. High amylase-containing rice would be flaky on cooking.

Bhattacharya, Sowbhagya, and Indudhara Swamy (1982) classified rice into eight types, based on its total and insoluble amylose content and alkali score. Rice varieties with total amylose content greater than 26% and insoluble amylose content between 12.5% and 15% were classified under Group II. Total amylose and insoluble amylose content of the three rice varieties are presented in Table 3. The total amylose content in all of the varieties of dehusked rice was found to be approximately 23%. Insoluble amylose equivalent varied from 12% to 14.4%. Hence, these three varieties could be classified under rice quality Group II (Bhattacharya et al., 1982). IR 64 contained relatively more soluble amylose content, compared to Njavara and Jyothi varieties.

Morphological characteristics like shape, size and distribution of starch granules are attributed to the biological origin of the rice (Svegmark & Hermansson, 1993; Vandeputte & Delcour, 2004). Rice consists of several polyhedral starch granules in a single amyloplast (Watson & Dikeman, 1977). The surfaces of starch granules in native rice samples were observed to be more or less smooth. Scanning electron microscopy (SEM) pictures of dehusked flour of Njavara and the other two varieties are presented in Fig. 1. Njavara flour showed spherical-shaped starch granules, whereas, Jyothi and IR 64 were irregular pentagonal or hexagonal shaped. The SEM pictures also showed fibrous structures, the protein matrix, along with starch granules. During cooking, the granule size of the starch increases/swells, due to water absorption. The shapes of the granules are maintained during swelling but as temperature increases irregular granule folding occurs, leading to disintegration and loss of shape. SEM of cooked rice of three rice varieties are also presented in Fig. 1. Cooking results in breakdown of the swollen semi-crystalline nature of starch molecules. This leads to irreversible changes in the starch properties, like granule swelling, loss of birefringence and crystalline order and starch solubility (Atwell,

Table 3
Amylose equivalent (content) of dehusked rice of Njavara and non-medicinal rice varieties

Variety	Moisture (%)	Insoluble amylose	Soluble amylose	Total amylose
Njavara	13.1 ± 0.2	14.3 ± 1.17	8.45 ± 1.35[a]	22.7 ± 0.78
Jyothi	13.0 ± 0.2	14.4 ± 1.21	8.47 ± 1.23	22.9 ± 0.47
IR 64	13.6 ± 0.3	12.6 ± 1.14	11.6 ± 0.69	24.3 ± 1.69

Values are mean ± standard error of four determinations.
[a] Significant difference ($P < 0.05$) between Njavara and IR 64.

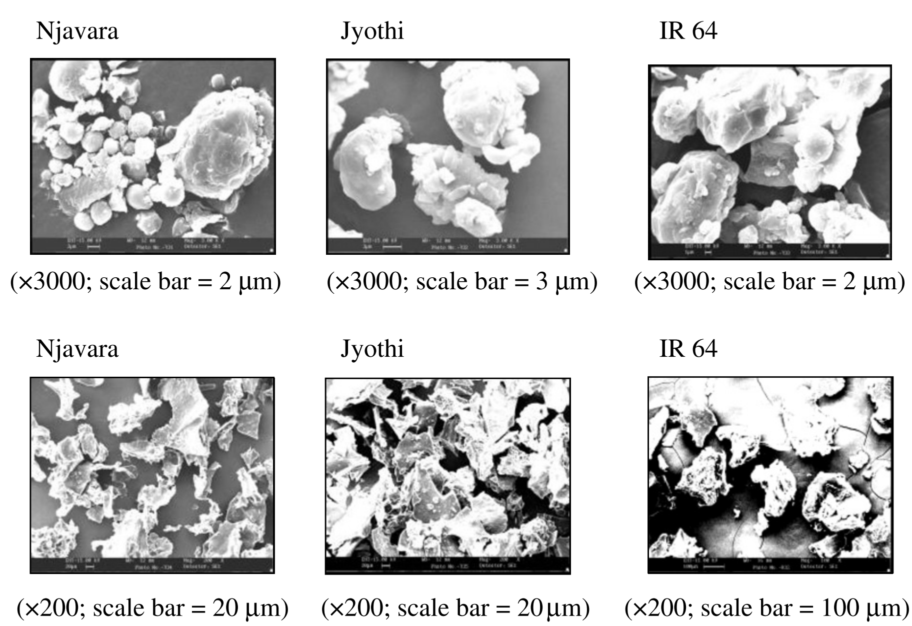

Fig. 1. Scanning electron micrographs of (1) native rice flours and (2) cooked rice.

Hood, Lineback, Varriano-Marton, & Zohel, 1988; Hoover, 2001). The changes occurring after cooking are clearly seen in the SEM photographs, Fig. 1 indicating leaching out, due to combination of linear molecules, dispersion of protein and fibre.

Cereals are the major source of carbohydrates, proteins, fats, minerals and vitamins to the vegetarian population worldwide. The proximate compositions of the three rice varieties are presented in Table 4. The moisture contents of all three varieties were ~13%, which indicates similar agro-climatic conditions and/or the place where the paddy was stored. In this study, one-year-old paddy of the three varieties were procured from different regions, stored at room temperature and used for proximate composition study. No significant differences were observed in carbohydrates, lipids and ash content among the three varieties of rice. Njavara had a higher protein content (~16%) than the other two varieties of rice. Wild rice (*Zizania aquatica*) has been reported to have a higher protein content than cultivated rice (Swain, Wang, & Hesseltine, 1978). The total dietary fibre content in Njavara was found to be significantly higher than Jyothi and IR 64. The ash content ranged from 1.30% to 1.54% in the three varieties of rice.

The vitamin content of dehusked rice of the three varieties is shown in Table 5. Njavara contained 27–32% higher thiamine, 4–25% higher riboflavin and 2–36% higher niacin compared to the other two rice varieties. Swain et al. (1978) reported 0.45 and 7.32 mg per 100 g for thiamine and niacin, respectively, in wild rice, which is comparable to that of Njavara. The high thiamine content in Njavara rice could be useful in treating muscle weakness, neuritis and other symptoms related to deficiency of vitamin B_1 (Menon, 2004).

Minerals are essential for normal metabolic functions and are required components in a balanced diet. Brown rice is an excellent source of minerals and as shown in Table 6, the mineral content of Njavara were found to be significantly higher than the other two rice varieties. Among the major minerals, phosphorus was found to be highest (354 mg per 100 g) followed by potassium (304 mg per 100 g), magnesium (216 mg per 100 g), sodium (30.8 mg per 100 g) and calcium (11.6 mg per 100 g) in Njavara. High potassium, calcium and magnesium could be helpful in improving muscle activity in patients suffering from muscle wasting.

Total fibre, soluble and insoluble fibre content of the three rice varieties is presented in Table 7. The total dietary fibre content in Njavara was found to be 34–44% higher than Jyothi and IR 64. The high insoluble dietary fibre contributed to the high fibre content of Njavara (Table 7).

The fatty acid compositions of Njavara, Jyothi and IR 64 are presented in Table 8. The fatty acids in dehusked rice were found to be 42.6% oleic acid (C 18:1), 31.0% linoleic acid (C 18:2), 22.1% palmitic acid (C 16:0), 2.4% stearic acid (C 18:0) and 1.54% linolenic acid (C 18:3). These values are comparable with lipids of Asian rice samples

Table 4
Proximate composition of brown rice of Njavara and non-medicinal rice varieties

Components	Njavara	Jyothi	IR 64
Moisture (%)	13.10 ± 0.15	13.00 ± 0.24	13.60 ± 0.32
Total carbohydrate (g per 100 g)	73.5 ± 13.21	72.8 ± 11.10	74.1 ± 17.6
Protein (g per 100 g) (N × 5.95)	9.52 ± 0.34[a,b]	7.97 ± 0.50	7.95 ± 0.17
Crude lipid (g per 100 g)	2.48 ± 0.50	2.60 ± 0.54	2.06 ± 0.14
Ash (g per 100 g)	1.42 ± 0.06	1.54 ± 0.09	1.27 ± 0.09
Fiber (g per 100 g)	8.08 ± 0.03[a,b]	5.82 ± 0.02	4.96 ± 0.01
Energy value (kJ per 100 g)	1630 ± 76.2	1570 ± 72.9	1660 ± 69.3

Values are mean ± standard error of five determinations. Njavara values were significantly different from
[a] Jyothi at $P < 0.05$.
[b] IR 64 at $P < 0.05$.

Table 5
Vitamin content of brown rice of Njavara and non-medicinal rice varieties

Vitamins (mg per 100 g)	Njavara	Jyothi	IR 64
Folic acid	0.05 ± 0.001	0.05 ± 0.002	0.04 ± 0.002
Thiamine	0.52 ± 0.01[a,b]	0.35 ± 0.01	0.40 ± 0.08
Riboflavin	0.071 ± 0.001[a,b]	0.053 ± 0.001	0.068 ± 0.001
Niacin	7.32 ± 0.81[b]	7.15 ± 1.04	4.68 ± 0.46

Values are mean ± standard error of five determinations. Njavara values were significantly different from
[a] Jyothi at $P < 0.05$.
[b] IR 64 at $P < 0.05$.

Table 6
Mineral compositions of brown rice of Njavara and non-medicinal rice varieties on a dry weight basis (mg per 100 g)

Minerals	Njavara	Jyothi	IR 64
Iron	1.93 ± 0.01	3.95 ± 0.22[a]	2.73 ± 0.32[b]
Calcium	11.6 ± 0.08[a,b]	9.70 ± 0.35	9.20 ± 0.46
Sodium	30.9 ± 0.14[a,b]	22.6 ± 0.05	27.8 ± 0.14
Magnesium	216 ±0.10[a,b]	150 ± 2.77	163 ± 0.05
Potassium	304 ± 0.48[a,b]	268 ± 0.69	248 ± 0.42
Phosphorus	354 ± 15.42[a,b]	324 ± 20.25	301 ± 2.43

Values were presented as mean ± standard error of five determinations. Njavara values were significantly different from
[a] Jyothi at $P < 0.05$.
[b] IR 64 at $P < 0.05$.

Table 7
Dietary fibre content of brown rice of Njavara and non-medicinal rice varieties

Dietary fibre (g per 100 g)	Njavara	Jyothi	IR 64
Insoluble fibre	7.56 ±0.05[a,b]	5.39 ± 0.0	4.43 ± 0.04
Soluble fibre	0.52 ± 0.03[a]	0.43 ± 0.02	0.53 ± 0.03
Total fibre	8.08 ± 0.03[a,b]	5.82 ± 0. 02	4.96 ± 0.01

Values are mean ± standard error of five determinations. Njavara values were significantly different from
[a] Jyothi at $P < 0.05$.
[b] IR 64 at $P < 0.05$.

Table 8
Fatty acid composition (%) in brown rice of Njavara and other non-medicinal rice varieties

Fatty acids	Njavara	Jyothi	IR 64
Palmitic acid (16:0)	22.1	22.5	21.4
Stearic acid (18:0)	2.4	2.4	2.2
Oleic acid (18:1)	42.6	43.0	44.1
Linoleic acid (18:2)	31.0	30.5	30.6
Linolenic acid (18:3)	1.54	1.63	1.54

Table 9
Triglyceride composition of Njavara and non-medicinal rice varieties

Triglycerides (%)	Njavara	Jyothi	IR 64
LLLn	0.62 ± 0.04	0.67 ± 0.04	0.65 ± 0.07
LLL	4.98 ± 0.33	3.69 ± 0.60	3.08 ± 0.13
LLO + LnOO	14.2 ± 0.18	13.2 ± 0.3	14.8 ± 0.24
PLL	10.6 ± 0.57	10.7 ± 0.26	8.56 ± 0.10
LOO + SLL	17.1 ± 0.20	15.7 ± 0.58	19.2 ± 0.08
PLO	21.2 ± 0.20	21.1 ± 0.37	21.9 ± 1.26
PPL	5.97 ± 0.25	7.14 ± 0.16	5.33 ± 0.19
OOO	10.7 ± 0.04	11.8 ± 1.18	12.4 ± 0.15
POO + LOS	12.6 ± 1.4	13.9 ± 0.88	11.7 ± 0.97
PPO	2.01 ± 0.57	2.44 ± 0.34	2.27 ± 0.14

P – palmitic acid, S – stearic acid, O – oleic acid, L – linoleic acid, Ln – linolenic acid.

(Lugay & Juliano, 1964). Fatty acid composition did not show any significant difference among the three varieties. The triglyceride composition of brown rice of the three rice varieties has been summarised in Table 9. Triglyceride composition of Njavara was found to be similar to that of the other two rice varieties.

In conclusion, this study showed that Njavara dehusked rice had relatively high protein, fibre, minerals and vitamins, compared to the two non-medicinal varieties Jyothi and IR 64. High thiamine and minerals such as potassium, calcium, magnesium, moderately high amylose content but slimy nature of the cooked rice, high fibre content, distinct pasting, thermal and viscography properties are characteristic of Njavara (to be communicated). These properties could be responsible for its usage as a vehicle, to facilitate the transfer of bioactive compounds from medicinal herbs and also to maintain heat during topical massage of the body in Njavara ayurvedic therapy (Njavara *kizhi*).

This is the first scientific report on the nutritional attributes of the medicinal rice Njavara. Further studies are in progress to characterise the bioactive phytochemicals, proteins and carbohydrates, in order to understand their physiological role and medicinal properties of Njavara rice.

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