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SHORT RESERECH ARTICLE

Elucidation of nutritional properties and cooking quality traits of under-exploited pigmented rice (*Oryza sativa* L.) landraces

Pushpa Raman, Sassikumar Datchinamoorthy*, Theertha Prasad, Suresh Ramalingam, Shanmugam Aravindan, Suresh K. Paramasivam[1], Arulmozhi Ramachandran and Subrahmaniyan Kasirajan

Abstract
The present study assessed five pigmented rice (*Oryza sativa* L.) landraces along with two commercial varieties. Protein (9.57 ± 0.18–12.46 ± 0.01%), zinc (19.9 ± 0.5–27.6 ± 0.4 µg/g) and iron content (10 ± 0.2–15.7 ± 0.2 µg/g) of the pigmented landraces were higher than varieties. With a high breakdown value, highest peak viscosity and low amylose, *Norungan* was classified as a high-quality cooking rice. Bold-type grains possessed higher amylose and resistant starch (RS) content compared to slender types. *Karun Kuruvai* recorded the highest RS content (7.0 ± 0.3%), which lowers the glycemic index. Therefore, there is a need to unravel these nutritional properties to develop a therapeutic variety.

Keywords: Resistant starch, protein, nutritional traits, rheological properties

Pigmented rice is widely known as nutritionally enriched rice with a unique taste with the presence of higher protein, zinc, iron, resistant starch, antioxidants, anti-diabetic and anticancer activity than milled or polished white rice. Furthermore, pigmented rice has a higher dietary fiber content than its well-milled counterpart. It has a lower glycemic index (Brotman et al. 2021).

In order to better understand the cooking quality and nutraceutical properties, the present study compared two non-pigment high-yielding popular rice varieties (CO51 and ADT53) with five pigmented landraces: *Mappillai Samba, Karun Kuruvai, Sivappu Kavuni, Poongar* and *Norungan*.The investigation was carried out at Tamil Nadu Rice Research Institute (TRRI), Aduthurai, Thanjavur, Tamil Nadu, India, between September 2020 and 2021. Gel consistency, alkali spreading value (ASV) (Singh et al. 2000), amylose content (Juliano 1972), protein content (Kjeldahl method using KELPLUS automatic nitrogen estimation system), zinc (Zn) and iron (Fe) (energy dispersive X-ray fluorescence spectrometry (XRF) method), resistant starch (Megazyme kit) and rheological properties (Rapid Visco Analyzer) were estimated.

Cooking properties

Mappillai Samba and *Poongar* belonged to the high amylose category, whereas *Norungan* as the low amylose group and *Sivappu Kavuni, Karun Kuruvai,* CO51 and ADT53 were found to be in the intermediate amylose group. Among the landraces, *Sivappu Kavuni* possessed the highest GC (105 ± 3.4 mm), whereas ADT53 and CO51 had 85 ± 3.4 and 80 ± 3.2 mm, respectively (Table 1). All the studied genotypes were found to have soft gel consistency (>60 mm).CO 51 and ADT 53 were found to be intermediate to high gelatinization temperature (GT) category based on the ASV value, while pigmented landraces were shown intermediate GT group. People favor intermediate GT rice varieties worldwide because overcooking high GT rice makes it too soft (Singh et al. 2020).

Department of Plant Breeding and Genetics, Tamil Nadu Rice Research Institute, Aduthurai 612 101, Thanjavur, Tamil Nadu, India.

[1]ICAR-National Research Centre for Banana, Tiruchirappalli 620 102, Tamil Nadu, India.

***Corresponding Author:** Sassikumar Datchinamoorthy, Department of Plant Breeding and Genetics, Tamil Nadu Rice Research Institute, Aduthurai 612 101, Thanjavur, Tamil Nadu, India, E-mail: sassikumar@tnau.ac.in

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Table 1. Cooking quality traits and resistant starch content of traditional rice varieties

Genotype	Grain Shape	GC (mm)	ASV	Amylose (%)	Resistant starch (%)
Mappillai Samba	LB	89 ± 0.8	5 ± 0.14	28.93 ± 1.0	5.14 ± 0.2
Norungan	LB	89 ± 1.6	5 ± 0.09	18.96 ± 0.8	6.13 ± 0.1
Poongar	LS	85 ± 1.1	4 ± 0.01	26.61 ± 0.9	4.86 ± 0.1
Sivapu Kavuni	LB	105 ± 3.4	4 ± 0.05	21.37 ± 0.8	6.47 ± 0.1
Karun Kuruvai	SB	96 ± 2.4	5 ± 0.03	21.80 ± 0.7	7.00 ± 0.3
CO 51	MS	80 ± 3.2	3 ± 0.08	23.6 ± 0.2	2.41 ± 0.1
ADT 53	MS	85 ± 3.4	3 ± 0.01	22.0 ± 0.2	2.08 ± 0.1

GC=Gelatinization consistency, ASV= Alkali spreading value, SB = Short Bold, LB = Long Bold, LS = Long Slender, and MS = Medium Slender

Resistant starch

All the pigmented landraces except *Poongar*had >5% resistant starch, whereas checks had around 2%. Resistant starch and glycemic index are inversely related to each other and the more the RS, the slower the digestion of rice and the lower is the GI (Kumar et al. 2018). The study identified that the mean RS content of the selected landraces was found to be 2.6 times higher than the checks used. In general, RS content in milled rice grain varies from 0.4 to 3% in the existing germplasm (Kasote et al. 2014). This shows that the rate of glucose released by these landraces after consumption was minimal as compared to non-pigmented rice varieties and these landraces can be useful to develop low GI varieties.

Rheological properties

Pasting temperature varied from 79.1 to 88.85°C. *Poongar* starch showed the lowest peak viscosity value, while *Norungan* starch showed the highest value (Table 2 and Fig. 1). Reduction in peak viscosity of *Poongar* starch might be due to the presence of the cross-linking groups, which may have interfered with the association of starch molecules with water. The final viscosity varied from 2511 (*Poongar*) to 6051cP (*Norungan*). *Poongar* starch showed a lower value, whereas *Norungan* and *Sivappu Kavuni* showed a higher value for breakdown viscosity, which makes the *Norungan* as good in palatability. In the case of setback viscosity, *Poongar* starch showed a lower value, whereas ADT53 starch

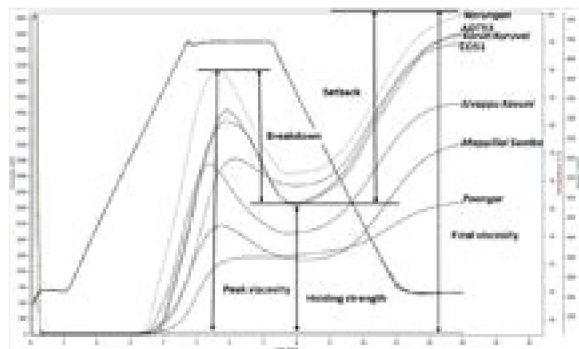

Fig. 1. **RVA profiles of traditional rice varieties**

showed a higher value. A higher value of peak viscosity and breakdown value with low amylose content is the indicator of good cooking quality rice (Han et al. 2021). Among the landraces and varieties, *Norungan* had the highest peak viscosity (4988cP) with a high breakdown value (1939cP) and was grouped under the low amylose category (18.96%).

Micronutrient and protein content

Karun Kuruvai possessed the highest Zn content in polished and unpolished grains, while for Fe content, *Sivappu Kavuni* had the highest Fe content in unpolished grains and in polished grains *Norungan* and CO51 possess 6.0 ± 0.09 and 5.9 ± 0.12 μg/g, respectively (Table 3). The zinc and iron content of pigmented rice was two to three times higher than that of white rice. Iron and zinc content drastically varied in polished and unpolished rice. During the polishing

Table 2. Starch pasting properties of traditional rice varieties

Genotype	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown (cP)	Final viscosity (cP)	Set Back (cP)	Peak time	Pasting temp (^{0}C)
Mappillai Samba	2063	1425	638	3600	2175	5.8	81.5
Norugan	4988	3049	1939	6051	3002	5.7	79.1
Poongar	1473	1445	28	2511	1066	6.73	88.85
Sivappu Kavuni	3231	1919	1312	4370	2451	5.4	80.75
Karun Kuruvai	3327	2818	509	5663	2845	6.13	83.3
CO 51	4263	2505	1758	5525	3020	5.93	84.10
ADT 53	4042	2470	1572	5700	3230	5.87	85.65

Table 3. Micronutrient content (Fe and Zn) of traditional Rice varieties

Genotype	Brown rice		Polished rice		Protein (%)
	Fe µg/g	Zn µg/g	Fe µg/g	Zn µg/g	
Mappillai Samba	11.7 ± 0.1	19.9 ± 0.5	1.1 ± 0.04	13.3 ± 0.28	11.7 ± 0.28
Norungan	10.3 ± 0.3	23.1 ± 0.7	6.0 ± 0.09	22.6 ± 0.48	12.5 ± 0.01
Poongar	10.0 ± 0.2	20.4 ± 0.1	2.0 ± 0.04	15.5 ± 0.60	10.2 ± 0.09
SivappuKavuni	15.7 ± 0.2	23.6 ± 0.7	1.3 ± 0.03	15.3 ± 0.67	11.0 ± 0.29
Karun Kuruvai	12.6 ± 0.1	27.6 ± 0.4	3.4 ± 0.13	23.4 ± 0.78	11.2 ± 0.30
CO 51	9.3 ± 0.3	19.6 ± 0.7	5.9 ± 0.12	14.1 ± 0.49	9.6 ± 0.18
ADT 53	9.8 ± 0.2	18.5 ± 0.3	3.0 ± 0.08	14.5 ± 0.27	9.9 ± 0.40

process, almost the entire aleurone and most part of the embryo are removed, which are the main storehouse for major micronutrients. It is estimated that more than 70% of micronutrients are lost during the polishing process (Sellappan et al. 2009). Bold grain types possessed higher protein content than the slender types. *Norungan,* which was a long bold grain type, had the highest protein content (12.5 ± 0.01%), followed by *Mappillai Samba* (11.7 ± 0.28%).

Identifying novel donors from the untapped germplasm and utilizing them to develop a high-yielding, nutrient-rich rice variety would be the ideal way to attain nutritional security. The present study has the aim to untie the nutritional and therapeutic properties of the traditional red rice varieties. Bold red rice landrace *Karun Kuruvai,* which is known for its nutritional superiority over the white rice varieties, possesses higher resistant starch (7.0 ± 0.3%) and zinc content (27.6 ± 0.4 µg/g) than other varieties. Protein-rich red rice *Norungan* and *Mappillai Samba* could be used to make rice products for breakfast, which includes flakes, bread and noodles. Therefore, there is a need to explore such types of resources in terms of functional quality, nutritional composition and health benefits to provide scientific data and, help the community in meeting nutritional problems and to develop a therapeutic variety to attain nutritional security.

Authors' contribution

Conceptualization of research (SD, SK, PSA); Designing of the experiments (SD, SK, SR, AR); Contribution of experimental materials (SA, SR, TP, SK); Execution of field/lab experiments and data collection (SD, PR, SK, SA); Analysis of data and interpretation (SD, SK, AR); Preparation of the manuscript (SD, SKP, PR, TP).

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