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Phytonutrients analysis in ten popular traditional Indian rice landraces (*Oryza sativa* L.)

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Abstract

Antioxidant potentials of native indigenous landraces of rice have been of great interest in the last decade, since a positive correlation of reduced chronic diseases due to consumption of rice has been established. Hence, the study focused on the analysis of phytonutrients in ten traditional rice landraces, such as in three pigmented (Mapillai samba, Kala namak and Iluppai poo samba) and seven non-pigmented (Poongar, Seeragasambha, Karnal, Kuzhiyadichan, Madumuzhongi, Salem sannam and Kitchili samba) varieties collected from different parts of India. Till date, there is no study on analyzing the phytonutrients in these traditional Indian rice landraces. The phytochemical analysis indicated Mapillai samba rice had highest vitamin E content ($26.73 \pm 0.49 \mu\text{g/g}$), whereas Kala namak rice showed highest phenolic content ($43.19 \pm 0.54 \text{ mg/g}$). The total flavonoid and anthocyanin contents were again highest in Kala namak $7.18 \pm 0.52 \text{ mg/g}$ and Mapillai samba $42.21 \pm 0.28 \text{ mg/g}$ respectively. The antioxidant properties and reducing power of the ten rice landraces were analyzed, among them Kala namak rice showed significantly higher antioxidants levels, inhibition of lipid peroxidation and reducing power. These results suggest that traditional land races possess higher vitamin E content and phytonutrients required to combat chronic diseases associated with their deficiencies. Among the varieties of rice tested, Kala namak pigmented rice variety had comparatively higher levels of vitamin E content and antioxidant potential. Hence, the pigmented traditional rice landraces can be used as a source of phytonutrients and it warrants conservation to preserve its precious genome information.

Keywords Rice landraces · Antioxidant · Phytonutrients · Vitamin E

Introduction

Rice (*Oryza sativa* L. family *Poaceae*) is a staple food for nearly two-third of the World's population and hence it is recognized as queen among cereals. Since Hudson et al. [1] demonstrated a positive relationship between the lower incidence of cancers and coronary heart diseases in Asian populations and rice consumption, great interests has been shown towards analyzing the phytonutrients of native rice varieties. The health benefits are numerous that even in continents like Europe and South America where rice is not considered a staple food have shown greater interests towards these native rice varieties. Rice is cultivated in almost all

the Indian states under a remarkably wide range of agroclimatic conditions and ecological situation [2]. Among various states, Tamil Nadu has been renowned as "Rice Granary of South India". About 400 varieties of rice are being cultivated in Tamil Nadu [3]. Traditional rice landraces like Madumuzhongi, Kuzhiyadichan and Poongar represents the gene pool for valuable traits. There is an urgent need for the collection and preservation of such varieties due to increased soil erosion and introduction of high yielding rice varieties [4]. Diets containing bioactive compounds such as, antioxidants have been on the fulcrum of research as consumers these days are more health conscious and the knowledge of health benefits from traditional foods and their derivatives has grown drastically over the years.

The idea is to bring back the traditional rice landraces not only for conserving the agro-biodiversity but to make use of several advantages including sustainability towards adverse climatic conditions like flood and drought, medicinal properties, nutritional value and high crop yield [5].

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Apart from the knowledge on traditional landraces, rice contains a significant number of natural phytochemicals such as oryzanols, tocopherols and tocotrienols that has been reported as strongest of antioxidants [6]. Genetic and environmental factors such as geographical locations, harvesting and climatic conditions are known to influence vitamin E content in the rice grain [7]. Content of vitamin E isomers varies among the rice varieties both within and between the grain colors. Recent reports suggest that the amount of γ -tocotrienol was found to be predominant in both pigmented and non-pigmented rice varieties cultivated in Malaysia [8]. Heinemann [9] reported that the amount of phytonutrients was found to be significantly higher in japonica rice than in indica rice counterparts cultivated in Brazil. Jiang [10] reported mineral contents and their correlation with the quantity of rice trait. However, some of the bioactive compounds like phenols, flavonoids and anthocyanins have not received much attention as much as the other components in rice grain. Phenolics are benzene ring aromatic compounds possessing one or more hydroxyl groups. In rice, Goffman and Bergman [11] studied the genotypic and environmental effects of the kernel phenolic content, and found that bran color had high statistical significance than bran phenolic contents. Flavonoids are group of phenolics, which consists of two aromatic rings linked by three carbons that are usually in an oxygenated heterocycle ring [12]. There have been few reports on characterization of other flavonoids such as flavones, flavanols, and flavanones. Srisawat et al. [13] studied the flavonoid content in Thai red and white rice cultivars and found that flavonoid content was three times higher in colored rice than those of white rice. Anthocyanins are reddish to purple water soluble flavonoids that are primary pigments in the red and black grains, and have been widely identified in cereal grains [14]. The major components of anthocyanidins in colored rice are cyaniding-3-*O*- β -glucoside and peonidin-3-*O*- β -glucoside. Recently, increased attention has been given to red and purple rice, which contains high amounts of hydrophilic phenolic compounds, including anthocyanins and proanthocyanidins [15]. Phenolic compounds are also known as antioxidants [14, 16]. Antioxidants have long been recognized to have protective functions against oxidative damage, and are associated with reduced risk of chronic diseases [17]. A recent report by Jun [18] fairly suggests that pigmented rice varieties show significantly higher amount of antioxidants than the non-pigmented varieties. Pengkumsri [19] reported that Chiang Mai Black rice was rich in free-radical-scavenging compounds than in Mali Red rice and Suphanburi-1 Brown rice cultivated in Northern Thailand. It is imperative to understand and validate certain functional components in rice that is beneficial to humans beyond the nutritional value of rice. The present study focus on the analysis of phytochemicals and antioxidants present in the popular South Indian rice

landraces, which have not been analyzed or reported before. This will be the first report in these indigenous varieties of rice as their potential bioactivity and antioxidant capacities were assessed by estimating total phenolics, flavonoids, anthocyanin contents, DPPH assay, total antioxidant assay and reducing power respectively.

Experimental procedures

Rice material

The rice samples used in this study were obtained from Mr. Nel Jayaraman, Consumer Research, Education, Action, Training and Empowerment (CREATE) trust, India. Out of 10 varieties, 8 were from southern states of India and two from the northern parts of India. The varieties were authenticated by Dr. S. Ganesh Ram, Department of Plant Genetic Resources, TNAU, Coimbatore. The list of rice samples used in this study is given in Table 1 and Fig. 1. Rice seeds were dehusked manually using forceps and ground to a fine powder for preparation of extracts.

Solvent extraction

Whole rice grain (1 g) of each cultivar was extracted with 25 mL of methanol containing 1% HCl for 24 h at 24 °C. The procedure was repeated twice. The methanolic extracts were centrifuged at 4000 \times g for 15 min and the supernatants were pooled and stored at 4 °C.

Preliminary phytochemical testing

The preliminary phytochemical investigation of methanolic extracts of different rice cultivars were performed as per the reported methods, to detect the various classes of phytoconstituents, such as total tocopherol content (vitamin E), phenolic compounds, flavonoids, anthocyanins and

Table 1 List of rice landraces used in this study

Cultivar name	Grain color	Location
(a) Kala namak	Black	Uttar Pradesh
(b) Mapillai samba	Red	Tamil Nadu
(c) Iluppai poo samba	White	Tamil Nadu
(d) Poongar	White	Tamil Nadu
(e) Seeragasambha	White	Tamil Nadu
(f) Karnal	White	Haryana
(g) Kuzhiyadichan	Red	Tamil Nadu
(h) Madumuzhungi	Red	Tamil Nadu
(i) Salem sannaam	White	Tamil Nadu
(j) Kitchili samba	White	Tamil Nadu



Fig. 1 Rice landraces used in the study **a** Kala namak, **b** Mapillai samba, **c** Iluppai poo samba, **d** Poongar, **e** Seeragasambha, **f** Karnal, **g** Kuzhiyadichan, **h** Madumuzhungi, **i** Salem sannam and **j** Kitchili samba

antioxidants. Total phenolics, flavonoids and anthocyanin contents in the methanolic extracts were analyzed using UV spectroscopy (Epoch BioTek, USA) as per standard procedures. All chemicals used in the experiments were procured from Sigma-Aldrich, USA.

Determination of vitamin E content

Total vitamin E content was determined using Baker and Frank method, which is based on Emmerie and Engle color reaction [20]. The formation of pink color at the final step of the reaction was spectrophotometrically (Epoch BioTek, USA) measured at 520 nm.

Determination of total phenolic content

Total phenolic content was assayed by Folin–Ciocalteu colorimetric method with gallic acid as a standard [21]. Briefly, 200 μ L of the appropriate dilutions of crude extracts was reacted with 1.8 mL of 10-fold diluted Folin–Ciocalteu reagent, (freshly prepared). The mixture was then neutralized with 1.8 mL of sodium carbonate (60 g/L). The absorbance was measured at 725 nm after 90 min of reaction at room temperature (RT). Results expressed as mg per 100 g of dry weight of the rice grain.

Determination of total flavonoid content

Total flavonoid content was determined using the aluminum chloride colorimetric method [22]. Approximately 1 mL of diluted extracts of different concentration was mixed with 3 mL of methanol, 0.2 mL of aluminum chloride, 0.2 mL of 1 M potassium acetate and 5.6 mL of distilled water. Allowed it to remain at RT for 30 min and then absorbance of the reaction mixture was measured at 415 nm with spectrophotometer (Epoch BioTek, USA) against methanol as blank. The total content of flavonoids in the rice extract was calculated by the following equation:

$$C = (c \times V)/m$$

where C is the total content of flavonoid compounds, mg/g methanolic extract, c is the concentration of standard quercetin established from the calibration curve in mg/mL, V is the volume of extract in mL and m is the weight of crude rice extract in g.

Total flavonoid content was calculated using the standard curve, and expressed as mg per 100 g of dry weight.

Determination of total anthocyanin content

Total anthocyanin content in the crude extracts of rice was determined by the pH-differential method with modification [23]. The methanolic extract was diluted in 0.025 M potassium chloride buffer, pH 1.0 and allowed to stand at dark RT for 30 min. Absorbance was measured at 520 and 700 nm (Epoch BioTek, USA) respectively.

Total antioxidant assay

Antioxidant assay was based on the reduction of Mo(VI)–Mo(V) by the extract and subsequent formation of a green phosphate/Mo(V) complex at acidic pH [24]. Extract (0.1 mL) was combined with 3 mL of reagent solution (0.6 M sulphuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate). The tubes were incubated

at 95 °C for 90 min. After the mixture had cooled to RT, the absorbance (Epoch BioTek, USA) of the solution was measured at 695 nm against a blank. The antioxidant activity was expressed as μM ascorbic acid equivalent (AAE) per 100 g dry weight of the rice flour.

Reducing power determination

The reducing power of rice extracts was determined as per the method of [25]. All the analysis were run in triplicates and averaged. Ferric reducing antioxidant power values were expressed as μM ascorbic acid equivalent (AAE) per 100 g dry weight of the rice flour.

Lipid peroxidation assay

Thiobarbituric acid assay was determined according to the method described by [26] with modification. Samples (50 mg) were added to 25 mL *n*-butanol. The solution was mixed thoroughly and 5.0 mL was added with 5.0 mL of 0.2 g/100 mL TBA in *n*-butanol or ethyl acetate. The solution was incubated for 2 h at 95 °C. The absorbance of the solution was measured at 528 nm. TBA value was expressed as the increasing absorbance due to the reaction of the equivalent of 1 mg sample per 1 mL volume with TBA, which was calculated by the following equation:

$$\text{TBA value} = [50 \times (\text{A sample} - \text{A reagent blank})] / \text{m}$$

where m represents mass of sample (mg).

Scavenging effect on DPPH radical

The free radical scavenging activity of the rice extract was measured by 1,1-dipheyl-2picryl-hydrazyl (DPPH) using [27]. All the analysis were run in triplicates and averaged.

Radical scavenging activity was expressed as inhibition percentage and was calculated using the formula:

$$\begin{aligned} \% \text{ Radical scavenging activity} \\ = (\text{Control OD} - \text{Sample OD} / \text{Control OD}) \times 100 \end{aligned}$$

Statistical analysis

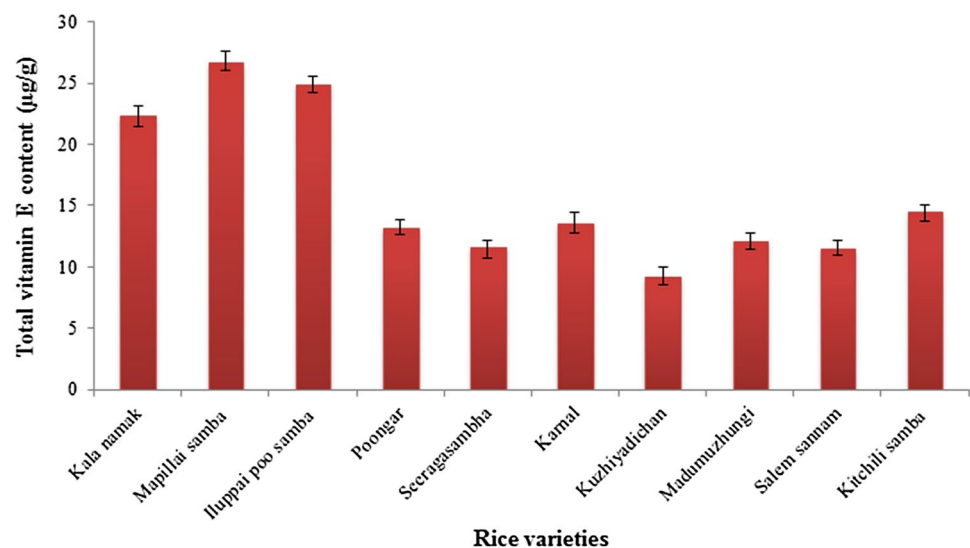
All the samples were analyzed in triplicates. The values were expressed as means of triplicate analysis of the samples ($n = 3$) \pm SD. All the data were further analyzed using one-way analysis of variance (ANOVA) followed by Duncan's multiple range test ($p \leq 0.05$) with the aid of SPSS, USA (Version 17) statistical package program. $p \leq 0.05$ was considered as indicative of significance, as compared to either control or between the varieties.

Results and discussion

Vitamin E content in traditional rice landraces

To investigate variations in the vitamin E content of traditional landraces, about ten different rice varieties were collected from different parts of South India. Significant variations in the vitamin E content were observed that ranged from 9.22 to 26.73 $\mu\text{g/g}$ for the ten samples analyzed (Fig. 2). The highest vitamin E content was recorded in pigmented rice varieties than the non-pigmented rice varieties. Mapillai samba showed the highest vitamin E content ($26.73 \pm 0.49 \mu\text{g/g}$) followed by Iluppai poo samba rice ($24.95 \pm 0.64 \mu\text{g/g}$) and Kala namak rice ($22.31 \pm 0.58 \mu\text{g/g}$) respectively. The vitamin E content values were found to be statistically significant for the pigmented varieties whereas between the non-pigmented varieties there were

Fig. 2 Vitamin E content of ten rice varieties



no significant differences observed. The vitamin E content was comparatively least in Kuzhiyadichan ($9.22 \pm 0.12 \mu\text{g/g}$) variety. The highest deviation in the concentration of vitamin E may be due to several factors like soil type, atmospheric CO_2 , chemical inputs, temperature, and degree of ripening [28]. The results obtained in this study are similar to [29], who reported higher vitamin E content in colored rice varieties like Taibalang black waxy rice ($85.49 \pm 3.24 \mu\text{g/g}$), black rice western Taiwan ($129.97 \pm 1.23 \mu\text{g/g}$), black rice Thailand ($137.28 \pm 9.75 \mu\text{g/g}$), Taibalang red waxy rice ($99.68 \pm 9.14 \mu\text{g/g}$), Guangfu red rice ($166.93 \pm 3.65 \mu\text{g/g}$) and red rice Thailand ($50.65 \pm 5.07 \mu\text{g/g}$).

Total phenolics content

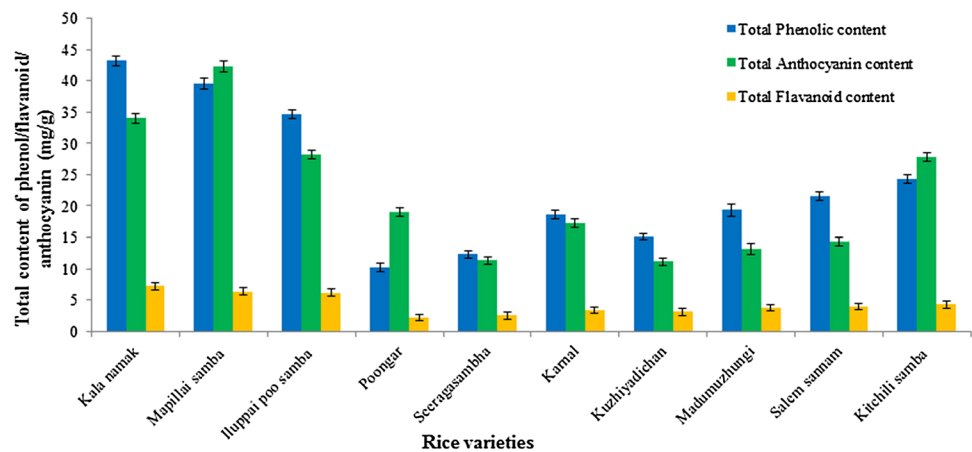
Phenolics are a group of natural antioxidants that has received considerable interest due to their pharmacological functions. Among the phenolic acids, ferulic and p -coumaric acids are abundant in grains with light brown pericarp, whereas red and black pericarp rice contain mainly the anthocyanins cyanidin-3- O - β -D-glucoside and peonidin-3- O - β -D-glucoside [30–32]. Higher TPC was observed for Kala namak $43.19 \pm 0.54 \text{ mg/100g}$, Mapilalai samba $39.56 \pm 0.50 \text{ mg/100g}$, Iluppai poo samba $34.61 \pm 0.75 \text{ mg/100g}$ and the lowest was with Poongar variety $10.23 \pm 0.22 \text{ mg/100g}$ (Fig. 3). Between the rice varieties tested the pigmented varieties showed statistically significant values for total phenolic content compared to that of non-pigmented varieties like Salem sannam, Seeragasambha and Madumuzhongi. A previous study by [23] on antioxidant activity of pigmented and non-pigmented Thai rice cultivars with various solvents reported that the total phenolic content of methanolic extract had higher values than distilled water, hexane and ethyl acetate extract. In another study, antioxidant activity of Iranian rice bran varieties extracted with three different solvents (methanol, ethanol and ethyl acetate) reported that the methanolic extract of Fajr variety had a higher total phenolic content

($3.31 \pm 0.03 \text{ mg GAE/g}$) than those of ethanol and ethyl acetate extracts, 1.67 ± 0.01 and $1.29 \pm 0.03 \text{ mg GAE/g}$, respectively [33]. Similarly, [34] reported that among pigmented rice from Sabah, Malaysia, red rice variety contained the highest quantity of phenolic acids ($329.93 \pm 19.17 \text{ mg/100g}$) than the black rice ($290.77 \pm 13.72 \text{ mg/100g}$), brown rice ($69.63 \pm 5.58 \text{ mg/100g}$), and the white rice variety ($22.59 \pm 1.31 \text{ mg/100g}$). The higher content of polyphenols in the dark pigmented rice grains (red and black) can be attributed to the difference in pericarp color. In addition to the variations in phenolic compound concentrations, variations were also observed in the concentration of these compounds in grains with the identical pericarp color [35]. Variations within the group with similar pericarp color was reported by [36], with concentrations varying from 108.1 to 251.4 mg GAE 100 g for light brown, 165.8 to 731.8 mg GAE 100 g for red, and 841.0 to 1244.9 mg GAE 100 g for black pericarp color rice grains, respectively.

Total flavonoid content

In rice, the phenolic compounds exist in both soluble and insoluble (bound) forms similar to other cereal grains [37]. The pericarp color pigments are derived from such polyphenols and the type, concentration of such polyphenols in the grain vary among genotypes. Plant phenolics like isoflavonoids and stilbenes have been found to be beneficial to human health [38]. Flavonoids can counteract cancer cell growth, as well as promote antioxidant, anti-inflammatory activities. The total flavonoid content ranged from 2.20 ± 0.11 to $7.18 \pm 0.52 \text{ mg/100g}$ rice extract (Fig. 3). Accumulation of anthocyanins has a direct relation to the coloration of rice [39]. Thus, it could be presumed that the white rice had flavonoid content lower than those of red and black pigmented varieties of rice. Statistically significant values were observed with the total flavonoid contents of pigmented rice compared to that of non-pigmented varieties which were observed to have no statistical significance

Fig. 3 Total phenolic, anthocyanin and flavonoid content in the ten rice varieties. (Color figure online)



except for the variety Kitchili samba. The highest flavonoid content was found in pigmented rice variety Kala namak, which had 7.18 ± 0.52 mg/100g; on the other hand, Poongar had the lowest flavonoid content of 2.20 ± 0.11 mg/100g. Among pigmented and non-pigmented rice varieties, the color parameters positively correlate with phenolics, flavonoid contents, and antioxidant capacity [36]. Our results are similar to that of [40] where black colored rice variety had the highest amount (0.028 ± 0.03 mg/g) of total flavonoids when compared to red (0.02 ± 0.02 mg/g) and white (0.023 ± 0.02 mg/g) rice varieties cultivated in Korea.

Total anthocyanin content

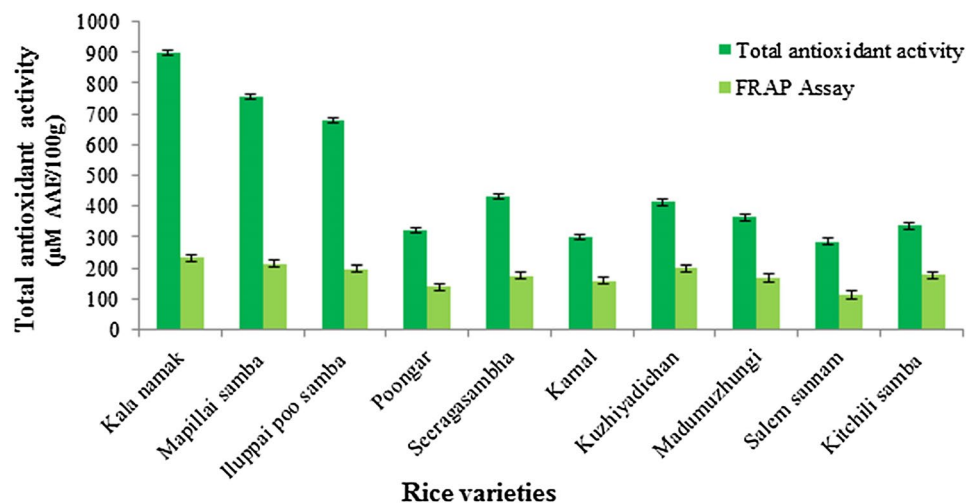
Anthocyanin pigments have been reported to be highly potent in reducing cholesterol levels in the human body [41]. Total anthocyanin content was found to be highest for pigmented varieties (Fig. 3), Mapillai samba 42.21 ± 0.28 mg/100g, Kala namak 34.01 ± 0.45 mg/100g, Iluppai poo samba 28.27 ± 0.26 mg/100g and lowest anthocyanin content was observed in non-pigmented rice variety Kuzhiyadichan 11.12 ± 0.18 mg/100g, respectively. The high content of total anthocyanins in the pigmented rice varieties were statistically significant whereas no statistical significance was observed between the non-pigmented varieties tested. The predominant flavonoids in pigmented rice varieties are the anthocyanins and kaempferol, quercetin were identified to be the dominant flavonols, whereas apigenin was the major component of flavones [40]. The structural properties of anthocyanins make them highly reactive towards reactive oxygen species (ROS) [42, 43]. A previous study on anthocyanin contents of pigmented rice in Thailand, China and Srilanka was reported by [44], where all rice varieties with black colored pigments had the highest amount of total anthocyanin compared to 10 red pigment varieties, black pigmented varieties have 109.52 ± 0.32 to

256.61 ± 7.66 mg/100g anthocyanin, while the total anthocyanin contents of red varieties varied between 0.33 ± 0.02 and 1.38 ± 0.07 mg/100g. A study on 8 different pigmented varieties in Thailand by [45], revealed that rice varieties with dark purple color contained a higher amount of anthocyanin ranging between 208.42 ± 3.53 and 329.24 ± 6.72 mg/100g, compared to the red pigmented varieties ranging between 58.89 ± 6.89 and 84.43 ± 3.61 mg/100g. Sutharut [46], reported that three rice varieties in Thailand, where a non-pigmented variety contained anthocyanin at a range between 1.09 ± 0.75 and 10.83 ± 5.20 mg/100g and a range of $17.89 \pm 0.12.20$ and 99.53 ± 18.87 mg/100g was reported for the two colored varieties. In this study, the total anthocyanin content was found to be slightly higher in pigmented rice than the previous reports.

Antioxidant activity

The antioxidant activity of ten different traditional rice landraces is shown in Fig. 4. The free radical scavenging activity of the rice extracts was found to be higher in pigmented rice varieties, Kala namak 897.10 ± 0.55 μ M AAE/100g, followed by Mapillai samba 756.23 ± 0.65 μ M AAE/100g and Iluppai poo samba 678.32 ± 0.78 μ M AAE/100g. The lowest antioxidant activity was found in non-pigmented rice variety, Salem sannam 284.81 ± 0.58 μ M AAE/100g. High level of antioxidant capacity in pigmented rice as compared to the non-pigmented rice could be attributed to the presence of high levels of total phenolic content. Statistically significant values were observed for the antioxidant capacities in the pigmented rice including Kala namak, Mapillai samba and Iluppai poo samba. We also observed statistically significant correlation between total flavonoid and anthocyanin content of the rice extracts studied. Reports suggests that the antioxidant capacity, screened in 591 rice cultivars including white rice, weedy red rice and pigmented rice, blackish

Fig. 4 Total antioxidant potential and FRAP assay in the ten rice varieties. (Color figure online)



purple rice cultivars showed twofold stronger antioxidant activity than the white rice cultivars [47]. The reason behind this is pigmented rice methanolic extracts had significantly higher amount of anthocyanins which is a potent reducing agent and possess strong radical scavenging activity. Walter et al. [35] demonstrated that the antioxidant capacities varied depending on pericarp color as lower antioxidant activity was observed for the rice grains with a light brown pericarp color compared to red and black pericarp grains. Similar results with red and black pericarp coloured grains have also been reported by [11, 36] using DPPH and ABTS assays.

Reducing power

Reducing power in Kala namak variety ($231.01 \pm 0.12 \mu\text{M AAE}/100\text{g}$) was higher than Salem sannam ($112.09 \pm 0.13 \mu\text{M AAE}/100\text{g}$) (Fig. 4), which was correlative with the radical scavenging ability. Among the rice varieties tested the pigmented varieties Kala namak, Mapillai samba, Iluppai poo samba showed statistically significant values when compared to the non-pigmented varieties. Tsuchihashi et al. [48] suggested that pigmented rice extracts contain components acting as electron donors which can terminate lipid peroxidation chain reactions, probably through conversion of lipid peroxy radicals to yield more stable products. Arab et al. [33] observed that the reducing power in Fajr rice ($50 \pm 0.03 \text{ mg}/\text{mL}$) (pigmented) variety was higher than Tarem rice (non-pigmented) ($47 \pm 0.04 \text{ mg}/\text{mL}$) which is cultivated in Iran. Sompong et al. [44] similarly reported values of FRAP at 7.6 ± 0.06 and $8.0 \pm 0.23 \text{ mmol Fe(II)}/100 \text{ g}$ in black and red rice varieties. Among the pigmented varieties there were positive correlations between the TPC values and that of DPPH, FRAP assays confirming the direct relationships between antioxidant activities, active phytoconstituents and density of pigmentation among the rice cultivars.

Inhibition of lipid peroxidation

Antioxidant activity using thiobarbituric acid (TBARS) assay was used for measuring malonaldehyde (MDA) formation, while MDA is the product of the oxidation of polyunsaturated fatty acids, considered as an index of lipid peroxidation. MDA products of crude rice extracts for each cultivar differed, the highest of MDA products were formed in Kala namak ($20.16 \pm 0.15 \text{ mg}/\text{g}$) and the lowest was observed in Seeragasambha $5.31 \pm 0.22 \text{ mg}/\text{g}$. The MDA products of pigmented and non-pigmented rice varieties are shown in Fig. 5. The MDA products among the pigmented varieties Kala namak, Mapillai samba, Iluppai poo samba showed statistically significant values. No statistically significant differences among MDA contents of non-pigmented rice extracts were observed. A study on thiobarbituric acid

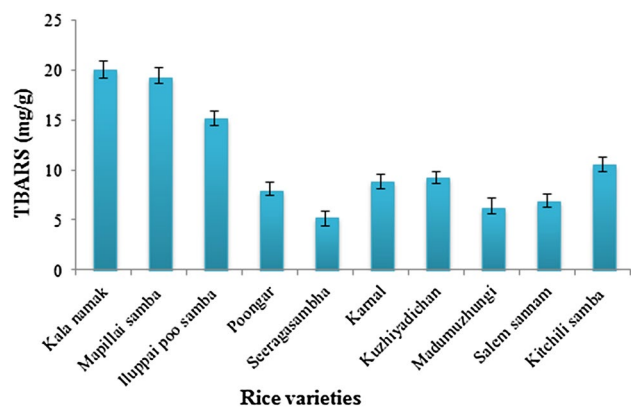


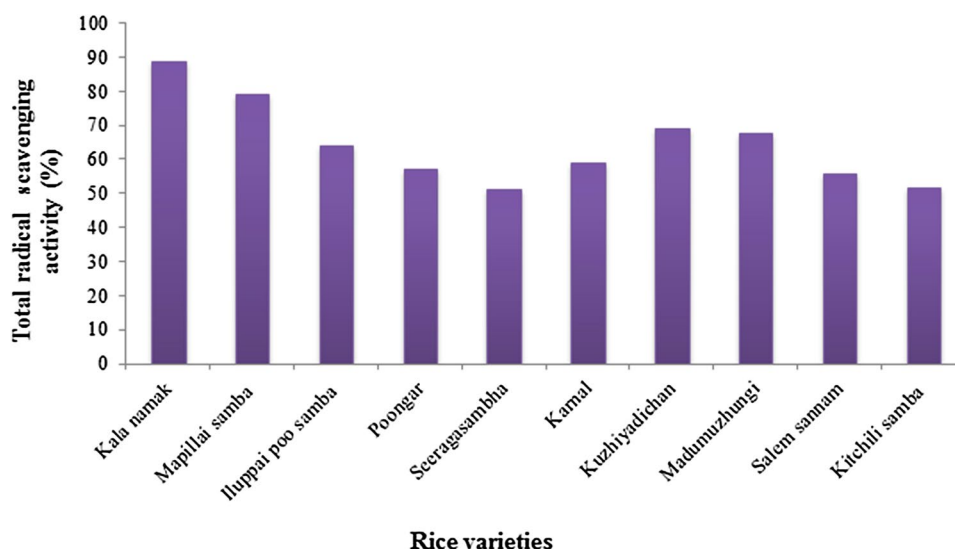
Fig. 5 TBARS assay in the ten rice varieties used in the study

assay from pigmented rice variety in Sabah, Malaysia by [34] reported that the red rice variety showed the highest antioxidant activity when compared to three other varieties with the lowest absorbance (0.329), black rice (0.364), and brown rice (0.411) with a significant difference ($p < 0.05$).

Radical scavenging activity

The antioxidant activity was determined with DPPH free radical scavenging for each cultivars of the crude rice extract and the average radical scavenging activity varied from 59.23–89.01% (Fig. 6). The highest percentage of radical scavenging inhibition was found in pigmented rice varieties, Kala namak (89.01%) and the lowest radical scavenging activity was observed in non-pigmented rice Seeragasambha (59.01%) which could be due to the low content of phytoconstituents. Variations were observed between the varieties of rice tested as the radical scavenging percentages of pigmented rice varieties Kala namak, Mapillai samba and Iluppai poo samba were observed to be statistically significant. Among the non-pigmented rice extracts there was no statistical significance observed between the varieties except Madamuzhongi and Kuzhiyadiichan. A similar study was reported by [49], investigating the methanolic extract of rice bran from four varieties in India, and they reported that the Njavara had the highest DPPH scavenging activity with an IC_{50} value $30.85 \mu\text{g}/\text{mL}$, and the IC_{50} values of the other varieties were 48.88, 70.58 and $87.72 \mu\text{g}/\text{mL}$ for Jyothi, Yamini and Vasumathi, respectively. Gasemzadeh et al. [50] reported a positive correlation between the concentration of phenolics ($288.40 \pm 14.35 \text{ mg}/100\text{g}$) and flavonoids ($156.20 \pm 10.69 \text{ mg}/100\text{g}$) in grains and their antioxidant potential ($84.2 \pm 3.84\%$). A strong correlation between the antioxidant activity and proanthocyanidins content was observed by [51] when experiments were carried out with black and red rice grains.

Fig. 6 DPPH scavenging activity of the rice extracts prepared from ten rice varieties



Conclusion

It is conspicuous that phenolics, flavonoids content and antioxidant capacity differ from the grain color; nonetheless these phytoconstituents and antioxidant capacity still vary among that of white color rice grains and pigmented grains. Our results highlight that the amount of bioactive compounds present in different genotypes of rice cultivated is related to the color of the pericarp (pigmented and non-pigmented). Pigmented genotypes showed fourfold higher levels of total vitamin E, phenolics, flavonoids, anthocyanins and antioxidants content compared to the non-pigmented rice varieties. The results of all parameters of phytochemical screening showed that Kalanamak, a pigmented rice variety emerged as a potent source of vitamin E, with phytoconstituents and free radical scavenging properties. It can be concluded that pigmented rice varieties might act as a potential natural antioxidant source. The landraces studied here can be utilized for major rice improvement strategies that have high nutritive, nutraceutical and medicinal values.

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Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

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