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RESEARCH ARTICLE

Evaluation of nutritional quality, physical characteristics and functional properties of organically produced variety of red rice (*Oryza sativa*)

Priyanka Joshi and Arti Sankhala

SUMMARY

The present study is an investigation to evaluate nutritional quality, physical characteristics and functional properties of organically produced variety of red rice (*Oryza sativa*). Results revealed that red rice contained 9.6 g crude protein, 1.7 g crude fat, 1.5 g total ash, 2.3 g crude fibre, 73.3 g carbohydrates, 347 kcal energy, 182 mg calcium, 1.76 mg iron and 1.52 mg zinc, respectively. Protein digestibility *in-vitro* of red rice was found to be 65.4 % whereas iron bioavailability was observed to be 0.27 mg/100g that pertaining to 15% availability of iron in the body. Anti-nutritional factors *i.e.* tannin and phytate content of red rice was found to be 0.29% and 0.96%, respectively. Red rice had a strong antioxidant property (75%). Results of physical characteristics and functional properties also showed that good water, oil absorption, emulsifying capacity. Organically produced variety of red rice were found to contain all essential nutrients and thus, can be recommended for regular use in daily diet to contribute various nutrients.

Key Words : Red rice, Nutritional composition, Antioxidant property, Functional property

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MEMBERS OF THE RESEARCH FORUM

Author to be contacted :
Priyanka Joshi, Department of Food Science and Nutrition, College of Community and Applied Sciences, Maharana Pratap University of Agriculture and Technology, **Udaipur (Rajasthan) India**
Email : priyanka_fn@yahoo.co.in

Address of the Co-authors:
Arti Sankhala, Department of Food Science and Nutrition, College of Community and Applied Sciences, Maharana Pratap University of Agriculture and Technology, **Udaipur (Rajasthan) India**

Rice (*Oryza saliva* L.) is one of the leading food crops of the world and is the staple food of over approximately one half of the world's population. About 90 % of the world's rice is grown and consumed in Asia (Tyagi *et al.,* 2004). Rice produced by organic farming has higher grain quality in terms of total recovery, proportions of head rice and broken on milling, grain appearance, grain size and shape, behaviour upon cooking, taste, tenderness and flavour of cooked rice, which is highly influenced by the nutrient management practices.

Recently, pigmented rice, such as brown rice, black rice and wild rice, have received the attention of consumers looking for healthier foods. The health benefits of pigmented rice are attributed to the presence of phenolic compounds that possess antioxidant, anticarcinogenic, antiallergic, antiinflammatory, antiatherosclerosis and hypoglycaemic activities (Deng *et al.,* 2013).

In this context, organically produced varieties of red rice are gaining more and more attention due to its several health and nutritional benefits. It is normally consumed as an unhulled or partially hulled form and has a red in tint due to the presence of anthocyanin pigment, which is located in outer layers of the rice kernel. It has a nutty flavour and has a higher nutritional value due to the germ portion being intact than the other variety of rice. Several studies conforms that it is beneficial in lowering cholesterol, blood glucose and the risk of obesity while helping with fighting against asthma and supports bone health. Red rice, unlike most other cereals, is consumed as a whole grain. Therefore, physical properties such as size, shape, uniformity and general appearance are of utmost importance. Furthermore, because most rice is milled, the important physical properties are determined primarily by milled endosperm.

Since rice is produced and marketed according to grain size and shape, the physical dimensions, weight, and uniformity are of prime importance. Grain - type categories are based upon three physical qualities: length, width and weight. Knowledge of the physical and mechanical properties of the rice is being used in the planting, harvesting, drying, storing, milling, and processing and cooking of rice. The functional properties are the significant physicochemical properties that are determining the complex interaction between the composition, structure, and molecular conformation. The information on the nutritional quality, physical characteristics and functional properties of red rice is rather scarce. Hence, this study was carried out to investigate the nutritional quality (proximate and mineral composition bioavailability of nutrients, antinutritional factors and antioxidant property) and physical characteristics and functional properties of organically produced red rice.

MATERIAL AND METHODS

Sample collection:

Organically produced variety of red rice was collected from "Banyan roots" an organic store of Udaipur city, Rajasthan. The sample was cleaned well to make them free from dust and grit, weighed and packed in poly bags.

Proximate analysis:

Red rice was ground using electronic food grinder before analysis. Proximate values, *i.e*. moisture, crude protein, crude fat total ash and crude ber in red rice samples were determined by Ofcial analysis methods of the AOAC (2000).

Mineral composition:

Mineral solutions of samples were prepared by wet ash method. The digested samples were analyzed by standard procedures *i.e.* calcium, iron and zinc were estimated using atomic absorption spectrometer (Bishnoi and Brar, 1988). The values are measured in ppm.

Protein digestibility *in-vitro*:

Dry sample of red rice was analyzed by the method of (Mertz *et al.*, 1984).

Iron bioavailability *in-vitro*:

Iron bioavailability *in- vitro* determination of red rice samples was done by using standard method of Lock and Bender (1980).

Anti-nutritional factors:

Anti-nutritional factors such as total tannin and phytic acid content were estimated using the method of Ataassova and Christova (2009) and Peach and Fracy, 1955, respectively.

Antioxidant activity analysis:

The concentration of total phenolic content in red rice was determined by the method of Mc Donald *et al.* (2001) and DPPH activity was analyzed by the standard procedure of McCune and Johns, 2002).

Physical characteristics:

No. of seeds in 10 g:

10 g seeds were counted manually and replicate 30 times.

Weight of 100 seeds:

100 seeds were counted manually and weighed using weighing balance (make least count, maximum count) and replicate 30 times.

Seeds volume:

It was assessed through method suggested by Bishnoi and Khetrapal (1993) in triplicate. Raw sample (BW) weighing 10 g were transferred to a measuring cylinder, where 10 ml distilled water was added. Seed volume was recorded after subtracting 100 ml from the total volume (ml).

Seed density:

It was determined through the method suggested by Bishnoi and Khetrapal (1993) in triplicate. 10 g of red rice was transferred to a measuring cylinder and 10 ml distilled water was added. Seed volume was recorded after subtracting 100 ml. Density was recorded as g per ml.

Bulk density:

Bulk density was assessed using the method suggested by Okaka and Potter (1977) fifty gram of the sample was placed in a 100 ml graduated cylinder and, then tapping the bottom ten times against the palm of the hand and expressing the final volume as g/ml.

Functional properties:

Water absorption capacity:

The method of Abbey and Ibeh (1998) was adopted for determination of water absorption capacity. The gain in mass was the water absorption capacity of the flour sample.

Oil absorption capacity:

Two (2g) of sample was mixed with 20ml of oil in a blender at high speed for 30sec. Samples were then allowed to stand at 30^0C for 30 minutes then centrifuged at 1,000rpm for 30 minutes. The volume of supernatant in a graduated cylinder was noted. Density of water was taken to be 1g/ml and that of oil determined to be 0.93g/ml.

Swelling index:

Three gram portions (dry basis) of red rice flour were transferred into clean, dry graduated (50ml) cylinders. The samples were gently leveled into it and the volumes noted. Distilled water (30ml) was added to each sample; the cylinder was swirled and allowed to stand for 60 minutes while the change in volume (swelling) was recorded every 15 minutes. The swelling power of each flour sample was calculated as a multiple of the original volume as done by Ukpabi and Ndimele (1990).

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Proximate analysis:

Perusal of data in the Table 1 clearly shows that the moisture content of red rice was found to be 11.6 g/100g. Current findings are relatively lower than the findings of Gopalan *et al.* (2007), who found that in raw and hand pounded rice, moisture content to be 13.3 g/100g. Hedge *et al*. (2013), who found that, the mean moisture content of organically grown red rice varieties was 7.91 g/100g which was relatively lower than the researcher value. The crude protein content of red rice was discerned to be 9.6 g/100g which was in accordance with the findings of Hegde *et al*. (2013), who found that, the crude protein content of organically grown red rice was 9.35 g/100g. Se *et al.* (2016) reported that the crude protein of three crossbreed red rice varieties ranged from

Table 1: Nutritional parameters of organically produce red rice

Nutritional parameters	(Mean $\pm$ SD)
Moisture (g)	11.6 + 0.39
Fat (g)	1.7 $\pm$ 0.47
Protein (g)	9.6 $\pm$ 0.51
Carbohydrate (g)	73.3 $\pm$ 1.01
Ash (g)	1.5 + 0.18
Fibre (g)	2.3 + 0.10
Energy (kcal)	347 + 1.67
Calcium (mg)	181.58 $\pm$ 2.38
Iron (mg)	1.76 $\pm$ 0.35
Zinc (mg)	1.52 + 0.21
Protein digestibility *in- vitro* (%)	65.4 + 1.34
Iron bioavailability *in-vitro* (mg/100g)	0.27
Percent availability of iron	15.0
Tannin (g/100g)	0.29
Phytate (g/100g)	0.96
Percent availability of iron	15.0
Total phenolic content (mg of CE/g)	12.4

7.03-8.23 g/100g. The protein content of rice is influenced by time and rate of nitrogen fertilizer application and type of fertilizer used. With respect to crude fat content, it was found to be 1.7 g/100g in red rice. Se *et al*. (2016) reported that the crude protein of three crossbreed red rice varieties ranged between 1.93-2.17 g/100g. But, Hegde *et al.* (2013) found relatively higher values of mean fat content *i.e.* 3.14 in organic red rice varieties. The ash content of red rice was detected to be 1.5 g/100g. In comparison to observation recorded in present study, the values of ash content quoted by Se *et al.* (2016) and Hegde *et al.* (2013) was in conformity for ash content *i.e.* 1.32 g/100g in UKMRC9 variety of crossbred red rice and 1.52 g/100g in conventional varieties of red rice. The crude fibre content of red rice was noted to be 2.3 g/100g which was relatively higher than those obtained by Hegde *et al.* (2013) and Gopalan *et al.* (2007), reported that organically grown red rice and raw-hand pounded rice contained 0.6 g/100g and 0.42 g/100g of fibre. The carbohydrate content of red rice was observed to be 73.3 g/100g which was in accordance with the findings of Gopalan *et al*. (2007) and Se *et al.* (2016), who found that carbohydrate content of hand pounded rice, was 76.7 and three crossbreed red rice varieties ranged between 76.2-78.4 g/100g. Since the carbohydrate content was calculated by difference method, the variation in carbohydrate content may be attributed to the differences in other constituents like fats, ash, fibre and protein of the samples. The energy content of red rice was found to be 347 kcal per 100g. The result of present finding was in line with the findings of Gopalan *et al.* (2007) reported that in raw and hand pounded rice, the energy content to be 346 kcal per 100g. Whereas, Se *et al.* (2016) reported that energy content of three crossbreed red rice varieties ranged between 354-364 kcal per100 g. Hegde *et al.* (2013) observed relatively higher values of energy content *i.e.* 374 kcal per 100 g in organically grown varieties of red rice.

Mineral composition:

Minerals are inorganic substances present in all living and non-living things including man, animals, rocks and soil. Their presence in living things is necessary for the maintenance of certain physiological processes (Hays and Swenson, 1985 and Ozcan, 2003). Table 1 delineates the mineral content found in red rice. It can be seen that the calcium, iron and zinc content were 18.58 mg/100g, 1.76 mg/100g, 1.52 mg/100g, respectively, in red rice. Diego *et al.* (2012) observed that the calcium and iron of red rice genotypes ranged from 12-18 mg per 100 g and 1.0-1.2 mg per 100 g, respectively which was more or less similar to researcher findings. However, the values of zinc content recorded in present study are comparable (1.4 mg/100g – raw hand pounded rice) with those mentioned in food composition table and slightly lower than the values (2.1-2.3 mg per 100g - red rice genotypes) reported by Diego *et al.* (2012).

Protein digestibility *in-vitro*:

As can be seen from the Table 1, protein digestibility *in-vitro* of red rice was found to be 65.4 %. According to Ali *et al*. (2010), a protein with high digestibility is potentially of a better nutritional value than the one with low digestibility because it provides more amino acids for absorption on proteolysis. The improvement in protein digestibility after germination, soaking and dry heating can be attributed to reduction of anti-nutrients such as phytic acid, tannins, polyphenols, which are known to interact with proteins to form complexes (Hassan *et al.*, 2006).

Iron bioavailability *in-vitro*:

Table 1 further shows iron bioavailability *in-vitro* and available iron of red rice. It was observed to be 0.27 mg/100g iron bioavailability and 15% availability of iron. Bioavailability of iron from food systems is an outcome of its interaction of its components. Phytic acid content of foods retains minerals in the intestinal lumen by forming insoluble complexes. The metal complexes of phytic acid may reduce the bioavailability of minerals such as iron, zinc, calcium and copper (Torre *et al.*, 1991). Studies have shown that the absorption of iron from typical Indian meals varied widely from about 2-10% (Rao *et al.*, 1983).

Anti-nutritional factors:

The data so obtained have been given in Table 1 which clearly shows that the tannin content of red rice was 0.29%. Tannins decrease the nutritive value of a product by binding protein, thus, reduce protein digestibility and also binding to amylase, thus, they block starch degradation. In the case of high tannin content in grain, their chelating effect is higher than that of phytates (Lestienne *et al*., 2005). The phytic acid content of red rice was noted as 0.96 g/100g which is slightly lower than the findings of Hegde *et al.* (2013), who found that, the phytic acid content of red rice to be 1.4 g/100 g.

Phytate and tannin not only interferes with mineral absorption, but also impair protein digestibility (Raghubanshi *et al.* 2001 and Gupta *et al*., 2006).

Antioxidant activity analysis:

Total phenol estimations:

The total phenol content, in the examined sample using the Folin-Ciocalteu's reagent was expressed in terms of catechol equivalent. The values obtained for the concentration of total phenols are expressed as mg of CE/g of extract. Perusal of total phenolic content as evident from Table 1 reveals that the total phenolic content is found to be 12.4 mg of CE/g in red rice. The values given by Hegde *et al*. (2013), were much higher. They reported that the total phenolic content of red rice was 16.7 mg/g. The level of phenolics in grains depends on such factors as cultivation techniques, rice breeding, growing conditions (e.g. altitude and fertilization), ripening process, as well as processing and storage conditions, among others (Min *et al.,* 2012; Naczk and Shahidi, 2006).

DPPH assay:

Table 1 extrapolates that the red rice has strong antioxidant activity at 100µl which showed 75.0% free radical scavenging activity. According to study carried out by Mishra *et al*. (2014), the antioxidant activity determined using the DPPH scavenging method was lower (61%) in red rice. They also reported that various processing treatments *i.e.* roasting, pressure cooking and microwave treatment significantly increased the antioxidant activities from 61% (native) to 84.64% (roasting). The content of antioxidative substances, *i.e.* polyphenol in rice grain, is affected by genotype and environment (Goffman and Bergman, 2004). The high antioxidant activity of any food samples can be correlated to the high phenolic content among the food sample (Thippeswamy and Naidu, 2005).

Physical characteristics:

The data so obtained for physical characteristics are presented in Table 2 revealed that red rice was found to be red in colour due to the presence of anthocyanin content. Red rice is elongated as it is 2 times lengthier the width. The no. of seeds in 10 g was 524 seeds and weight of 100 seeds was found to be 1.98 g seed. Seed volume, seed density and bulk density of red rice was observed to be 1.7 ml, 1.58 g/ml, $0.742 g/cm^{-3}$, respectively. The knowledge of bulk density is useful for the design of silos and hoppers for grain handling and storage. Since higher bulk density implies lesser packing space requirement, the rice varieties studied will require lesser packing space than those reported by previous authors (Thakur and Gupta 2006 and Varnamkhasti *et al*., 2008).

Table 2: Physical characteristics of red rice

Physical parameters	(Mean ± SD)
No. of seed in 10 g	524 + 3.61
Weight of 100 seed (g)	1.98 ± 0.01
Seed volume (ml)	1.7 ± 0.058
Seed density (g/ml)	1.58 ± 0.33
Bulk density (g/ml)	0.742 + 0.21

Table 3 showed functional properties of red rice *i.e.* water and oil absorption capacity, emulsifying activity and capacity hydration capacity and hydration index and Swelling capacity and swelling index of red rice. Result revealed that water absorption capacity of red rice flour was found to be 105.3%. Water absorption capacity is the ability to retain water against gravity and includes bound water, hydrodynamic water, capillary water and physically entrapped water (Moure *et al*., 2006). The water absorption capacity of soaked grain affected the mechanical behavior of grain during processing operations like wet milling (Ituen *et al.,* 1985) and could also have textural implications for the cooked product.

Table 3: Functional properties of red rice

Functional parameters	(Mean ± SD)
Water absorption capacity (%)	105.3 + 4.40
Oil absorption capacity (%)	123 ± 2.93
Emulsifying activity (%)	0.51 ± 0.01
Emulsifying capacity (%)	0.50 ± 0.02
Hydration capacity (g/seed)	0.006 + 0.001
Hydration index	0.32 + 0.04
Swelling capacity (g/seed)	0.01 + 0.002
Swelling index	0.33 + 0.01

Oil absorption capacity has been attributed to the physical entrapment of oil. It is an indication of the rate at which the protein binds to fat in food formulations (Hasmadi *et al*., 2020). Oil absorption capacity of red rice flour was 123%. The higher oil absorption capacity of flour is equally important as it improves the mouth feel and retains the flavor. Fat emulsion capacity is the extent to which the dietary protein will would dietary oil into fine particles. It directly measures the extent to which the dietary protein will mix oil (Abulude *et al.,* 2013). Emulsifying activity and capacity of red rice was found 0.51% and 0.50%, respectively. Hydration capacity and hydration index of red rice was found to be 0.006 g/seed and 0.32, respectively. Swelling capacity and swelling index red rice seed was 0.01g/ seed and 0.33, respectively.

Conclusion:

It can be concluded from the present investigation that red rice were found to contain all essential nutrients. It has higher content of crude protein, crude fiber, minerals and antioxidants than white rice or polished rice that are extensively available in the market. Hence, it can be recommended for regular use in daily diet to contribute various nutrients. Moreover, red rice products probably act as a product that gave the potential source of locally agriculture products to be usefulness in the future.

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