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Rice Products and their Nutritional Status

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FOREWORD

India produces over 285 million tons of food grains every year of which the share of rice alone is about 115millions tons. There is unique diversity of culture, lifestyle, religion and food habits amongst different states of India. Rice is being utilized in various forms for making different traditional and ethnic foods since long period of time. Though, there have been significant developments in the post-harvest technologies and rice-based food processing still there is plenty of scope for value addition and commercialization. Better food processing and value addition in rice would ensure better quality of end product, so as to provide better nutrition, better marketability and also higher return to the growers, processors and other stakeholders, while satisfying the consumers' needs and preference.

Indian people, particularly the rural women, are traditionally skilled and highly experienced in making innumerable varieties of rice-based value-added products. The present compilation 'Rice Products and Their Nutritional Status' describes some nutritional aspects of rice-based value-added products prepared across different Indian states. In the era of first food and packaged products, these rice products have immense importance with respect to human health and functional foods. I congratulate the authors for bringing out this informative and useful document for everyone having interest in rice and its various products.

H. Pathak

(Director, ICAR-NRRI, Cuttack)

PREFACE

Rice (*Oryza sativa* L.), the most popular cereal crop, is consumed as a staple food in the form of boiled, popped, puffed and beaten rice because of its significance in providing basic nutrition. Rice parboiling, a hydrothermal process is responsible to modify the qualitative and processing behaviour of rice while puffing and popping result in some physical, conformational and structural changes in rice grain due to reorientation of the starch granules leading to altered morphology and texture of the rice grain.The processing involving a hydrothermal change of rice grains into popped, puffed, boiled and beaten rice modifies the concentration of some phytochemicals in kernels.

In India, boiled rice is consumed in most families and prepared by boiling raw or parboiled rice with water followed by draining of excess water. This process leads to removal or conversion of a major part of the nutrients of rice grains to unavailable form. The preparation of other products such as popped and puffed rice, which require much higher temperature, probably register differential quantity of nutritional compounds than conventional boiled rice. The different rice products vary in their physico-chemical properties depending on processing methods.

Our study reviews the nutritional composition of different rice products and their associated antioxidant activities. The bulletin provides information on the traditional rice products and their nutritional composition and benefits. The product making quality of rice genotypes and their biochemical basis are important factors to appropriately considering the rice cultivars for the particular purpose. We tried to elucidate the genotypic variations of some biochemical factors responsible for making better quality products. We also discussed about the recent trends of rice products, present world-wide and some unconventional innovative value-added products based on rice and their by-products.

We thank of the scientists of Crop Physiology and Biochemistry Division, ICAR-NRRI and others who provided support and valuable information to enrich this research bulletin.

CONTENT

Introduction

Rice (*Oryza sativa* L.), the most popular cereal crop, is consumed as a staple food in the form of various processed products. Rice grain is harvested as rough rice after attaining maturity. The grain is generally stored at 12 to13% of moisture content for obtaining higher head rice recovery and better cooking quality. The grain is dehusked and milled by hulling and milling machine to get brown rice and milled rice, respectively. Milling of brown rice is generally performed to increase the storability. Some varieties in which the kernel fused with some bran layers after milling are reported to contain higher phenolic compounds (hydroxybenzoic acids and hydroxycinnamic acids), flavonoids, minerals (iron and zinc), proteins, vitamin-E, γ-oryzanols and different proximate compounds as compared to white rice. In India, the rice grain have been utilised for making several products. The processing is mainly based on hydrothermal treatments of different forms of the grain. For every instance, the reorientation of starch granules is occurred. Amongstall the products, puffed rice is very popular in many countries asa breakfast component due to its lightness and crispiness. It is prepared from treated (hydro-heated i.e., double parboiling) milled rice by heating in hot sand (200-300°C), or also from raw milled rice in microwave oven or by the puffing gun. Puffed rice provides less calories compared to cooked rice. Popped rice is a popular snack food in the south East Asian countries. It is prepared by putting moisture-adjusted paddy to high temperature, short-time treatment in sand medium, when the inner grain expands and is forced out through the opened husk like a flower. However, popping percent depends upon the genotypes. It is highly nutritious having more antioxidative compounds as compared to others. Flaked rice is obtained after hydrothermal processing of paddy and its further processing in a machine yields flaked rice of very low thickness with

relativelylower weight. Flaked rice generally consumed as breakfast item and snacks, is specific to particular regions in India, Bangladesh and a few Asian countries. Flaked rice is rich source of carbohydrates, protein, vitamin-E, minerals (Fe), phytochemicals, and essential amino acids. Finally, cooked rice in different forms is very popular throughout the world though it is less nutritious than other products. It is most popular due to easy preparation technology and better sensory quality. There are two ordinarily home-cooked products found in Asian countries: rice porridgeand cooked rice. A negative correlation between thermal processing and the content of antioxidative compounds, such as phenolic, flavonoids, vitamins etc. has been observed. Rice is also utilised for making different ethnic foods, which are consumed by the people of different religions and races on the occasion of different rituals and festivals of India. Almost all the preparation techniques are based on hydrothermal treatments. Therefore, information regarding nutritional profiling of various rice products is necessary for understanding our daily intake of nutritional compounds through rice.

Common Rice Products

The products of rice grain can broadly be categorised in two based on processing methods i.e., directly from grain and mixing with other ingredients. Cooked rice, popped rice, puffed rice, flaked rice, fermented rice, fried rice, rice *papad*, etc. can be prepared directly from grains. Similarly, dhosa, idli, rice cake, noodles, pasta, etc. can also be prepared from rice grain, mixing with other ingredients. Physical nature of these productsdepends on variation of different chemical constituents and starch orientation of the grain, which signifies a wide selection of the suitable rice cultivars for it. Therefore, information regarding retention of the nutritional components in various products is very important for product making quality of rice cultivars as well as for our health. The parameters which directly influence the consumer's acceptance and product making quality are physical, textural and other sensory quality of rice grain and the products. However, nutritional components are also very important as physical and sensory quality of the grain. Nutritional components of rice grain can be classified as different types of minerals, vitamins and plant metabolites (primary and secondary). Some researchers demonstrated that the total phenolic and flavonoids content as well as antioxidative capacity decreases by 10-20% at the time of puffing as compared to raw rice. However, parboiling is reported to enhance the antioxidative capacity marginally under DPPH assay, which results from the formation of brown pigments by the *Maillard* reaction. Here we report the quantitative assessment of some essential nutritional compounds of various rice products, which we consume very commonly.

It has been reported that brown rice has better nutritional composition but unfortunately it cannot be preserved for long period unless parboiling is done. In Indian market, though brown rice is available at higher price but its consumption is not so popular among common people because of higher price, poor keeping and sensory quality. Rice bran contains many phytochemicals like antioxidants, vitamins, proteins, minerals, which are beneficial for cardiovascular disease and diabetes. Direct consumption of stabilised bran (by microwaving the bran for 1.5 min in 900W) is very effective for lowering the cholesterol level in blood. However, consumption of popped rice, fermented rice and parboiled rice are the healthy options for getting some more nutritional benefits as compared to others as popped rice contains bran layers, attached with endosperm; higher mineral (iron and zinc) content was reported in fermented rice and for the diabetic people parboiled rice is better for it's slow releasing pattern of sugars in the blood. But the genotypic variation of different rice products are yet to be studied in the light of physical, sensory, minerals and nutritional qualities.

Conventional methods of preparation of rice products

After attaining maturity, rice grains are harvested and simultaneously sun-dried for few days. After 3-4 months of preservation at dry cool place, the grains are processed according to the need of the consumers. Generally, 12 -13 % moisture content of the grain is preferable with respect to storability and head rice recovery. The brief methodology for the preparation of various rice products are given below:

1. Brown rice: Mature grains of paddy i.e., rough rice with 12-13% moisture content are dehusked through hulling machine to obtain brown rice, where bran layers are completely attached with endosperm.

2.*Raw milled rice*: The brown rice is milled through rice milling machine up to 10-20% reduction in weight. This can be obtained after 1 to 2 minute milling of brown rice.

3. *Parboiled rice:* Rough rice is soaked in water for 8-10 hours for hydration of endosperm. After decanting of water, it is boiled (or steamed) for 1-2 hours until rupturing of husk is occurred. Then it is heaped for 1 hour and subsequently sundried for 2-4 hours until the moisture content of the grain attains 13-14%. This is called single parboiling. But, for specific purpose and consumers' preference, double parboiling can also be done through the repetition of the same process.

4. *Popped rice*: The rough rice is put into heated sand (>175ºC) in an iron pan for 40-50 seconds with continuous stirring. The husk of most of the grains getsdetached from the kernel during heating.

5. *Puffed rice:* The polished double parboiled rice is roasted with 10-12% brine solution for 1-2 minutes with constant stirring and then transferred to preheated (approx. 220°C) fine sand. Finally constant stirring (for 15-20 seconds) of rice in sand container produce puffed rice, which are separated from sand by the separator.

6. *Flaked rice*: Paddy is cleaned and graded to remove impurities and then it is soaked overnight followed by hot water (approximately 60˚C) treatment for about 45 minutes. After drying it is roasted slightly to make flakes with the flake making machine.

7. *Boiled rice:* It can be made from the raw or double parboiled rice with rice cooker, pressure cooker or by simple boiling in water.

8. *Fermented rice:* It can be prepared from raw or parboiled rice. The cooked rice is subjected to anaerobic fermentation overnight at room temperature (30^{0}C) with normal water and can be served in the next day with different ingredients.

9. *Rice noodles:* Rice noodles are made from flour containing high amylose concentration (>22%), which contributes to the gel network. They are commonly prepared by two main methods: sheeting of dough to develop flat noodles and extruding to develop vermicelli.

*10.Rice pasta:*Rice flour is blended with water in order to produce a mixture with final moisture content of 40%. Pasta is produced by an extrusion cooking process after hearing the mixture for 2 min, and then it is exposed to steam at115^{0}C. Heat-treated dough is then extruded into small pellets by the specialised machine. The pellets are then subjected to drying.

Retention of nutritional components in different rice products

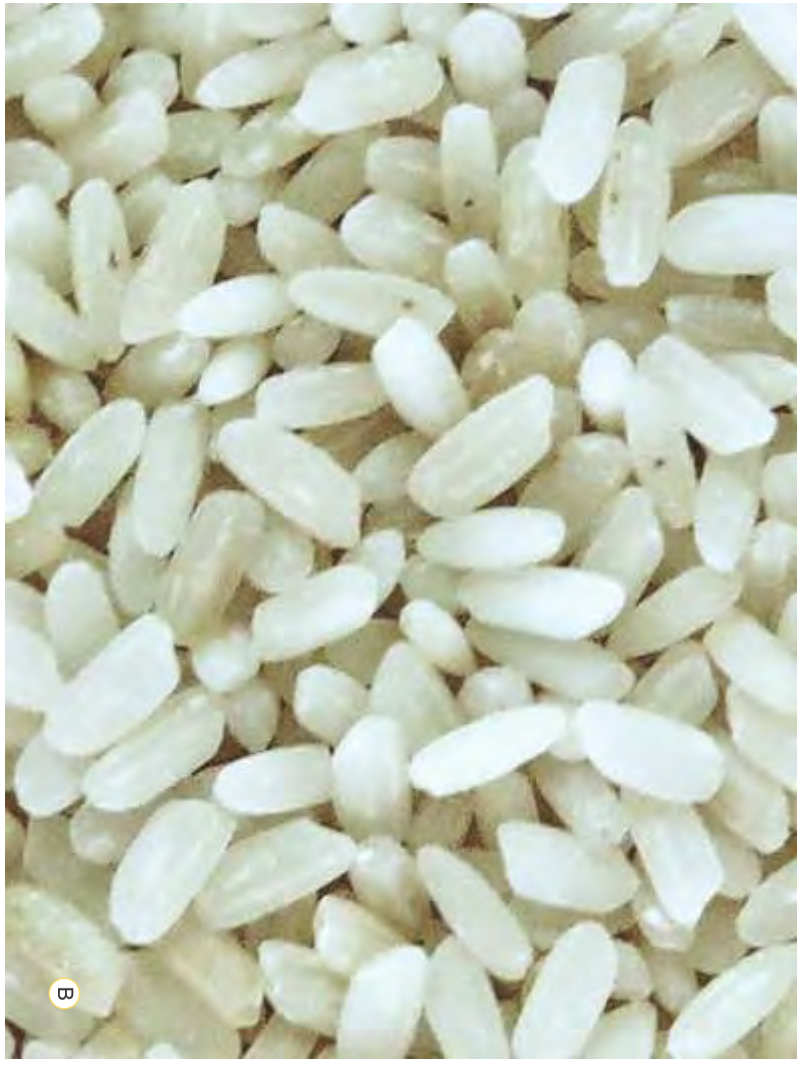
Amylose is the main biomolecule that determines the texture of cooked rice i.e., stickiness or looseness of the grain after cooking. It is the straight chain polysaccharide with little or no branching whereas amylopectin is highly branched. Higher amylose content (>20%) is generally associated with looseness of cooked rice and vice-versa. It also determines popping and puffing quality of rice. Amylose content was less affected by different ways of grain processing (Table 1). Grain protein content (GPC) is another significant factor in the nutritional quality of rice for it's hypoallergenic nature. Among available rice germplasm, a wide range of variability in GPC (5-18% with an average of 7.5%) is observed. Milled rice consists of about 78% starch, while protein is the second most abundant constituent (6-7%). Rice bran contains high level of fat (5-10 %) and protein (11-15%), as well as fibre (7-11%). Rice protein is made of four fractions viz.

glutelins, albumins, globulins and prolamins. Among these, glutelins form the major share (nearly 70–80%). Brown rice followed by parboiled polished rice contain higher amount of protein while cooked rice contains least. Among different products, popped rice is better with respect to retention of protein in the grain as bran layers are attached with endosperm. Antioxidants are molecules or enzymes that quench free radicals and inhibit cellular damage. Antioxidant defence is universal and differs from species to species. Antioxidants exist both in enzymatic and non-enzymatic forms in the intracellular and extracellular environment. Non-enzymatic antioxidants such as vitamin C, vitamin E, plant polyphenols, carotenoids, γ-oryzanol and glutathione work by interrupting free radical chain reactions. The highest DPPH (2,2-diphenyl-1-picrylhydrazyl)antioxidant activity was found in brown rice followed by fermented rice whereas flake rice, milled rice and boiled rice (parboiled) contain least.Antioxidant capacity of a product depends on presence and contents of a diverse array of hydrophilic or hydrophobic compounds including phenolic acids, γ-oryzanol, vitamin-E, anthocyanin and flavonoids in the grains. However, flavonoids, owing to its heat instability, were partially destroyed due to thermal treatment during the puffing process.

Table1. Nutritional composition of different products, derived only from rice grain (variety Swarna).

Sl. No.	Rice products	Amylose (%)	Protein (%)**	Antioxidant (DPPH)	Phenolics mg CEq/g)	γ-oryzanol (mg/g)	Vitamin-E(µg/g)	Iron (ppm)	Zinc (ppm)
1	Brown rice	25.41^{D}	7.84^{A}	30.92^{A}	3.86^{A}	0.31^{A}	21.50^{A}	30.50^{A}	57.20^{A}
2	Milled rice (raw)	25.91^{C}	7.05^{D}	15.50^{H}	2.60^{G}	0.12^{H}	12.50^{F}	5.20^{H}	19.20^{C}
3	Parboiled polished rice	21.20^{F}	7.55^{B}	20.85^{E}	2.20^{H}	0.20^{E}	13.60^{E}	6.10^{E}	18.20^{E}
4	Cooked rice (parboiled)	20.30^{G}	6.12^{F}	15.52^{G}	2.10^{I}	0.18^{G}	9.80^{G}	5.80^{F}	17.40^{G}
5	Cooked rice (from raw)	20.10^{H}	5.45^{H}	18.62^{F}	2.60^{F}	0.09^{I}	7.30^{H}	4.80^{I}	16.90^{H}
6	Popped rice	25.40^{E}	7.14^{C}	27.24^{C}	3.08^{C}	0.18^{F}	17.60^{B}	27.90^{B}	NA
7	Puffed rice	26.90^{B}	5.54^{G}	22.12^{D}	2.86^{D}	0.21^{D}	14.40^{C}	5.40^{G}	17.60^{F}
8	Flake rice	27.50^{A}	6.97^{E}	14.24^{I}	2.71^{E}	0.24^{C}	13.90^{D}	7.30^{D}	18.20^{D}
9	Fermented rice	20.30^{G}	NA	28.24^{B}	3.10^{B}	0.26^{B}	NA	22.80^{C}	35.80^{B}
	P value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

**Source: Liu K et al.(2019) andMir et al.(2016), **Juliano BO (1985b),Joshi N D. (2013)*


B


A

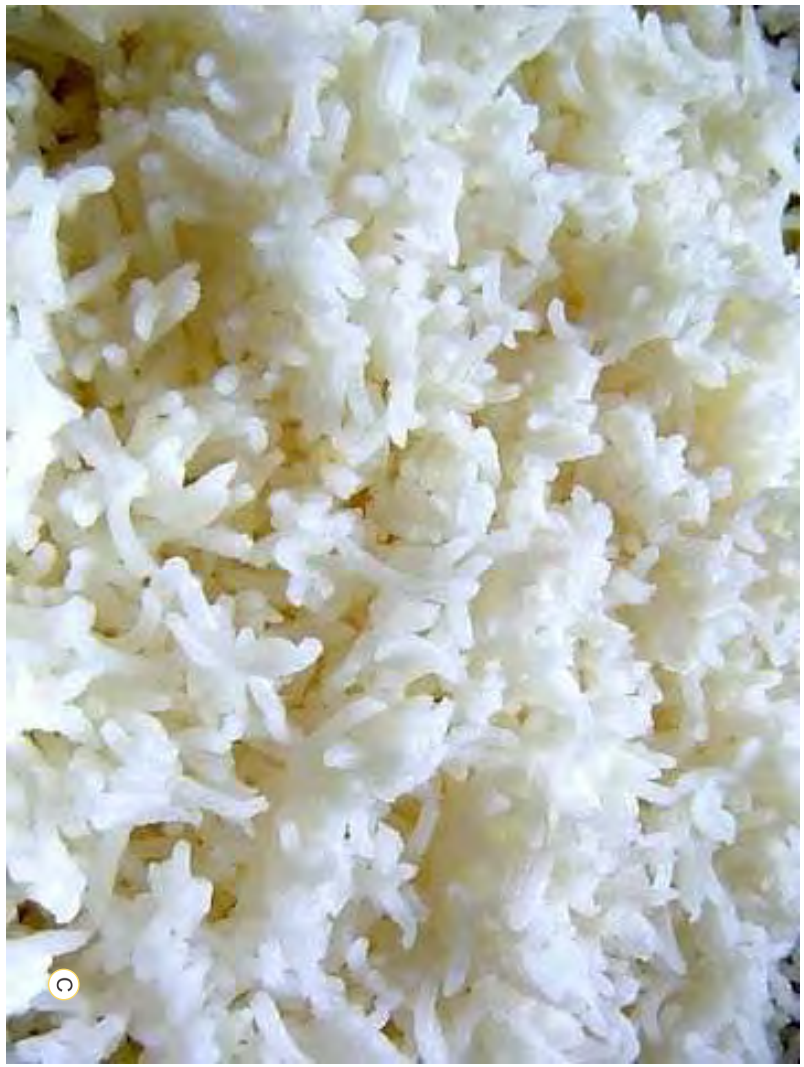


Fig.1. Different products from rice.

Note: A, Brown rice; B, Raw polished rice; C, Cooked rice; D, Popped rice; E, Puffed rice; F, Flaked rice; G, Fermented rice.

Higher antioxidant activity of popped rice is associated with enhanced surface area, presence of bran and greater exposure of antioxidants to DPPH radicals. Phenolics are aromatic secondary plant metabolites widely distributed throughout the plant kingdom. Approximately 8000 naturally occurring compounds belong to the category of phenolics all of which share a common structural feature: an aromatic ring bearing at least one hydroxyl substituent i.e., a phenol. These naturally occurring phenolic acids contain two distinctive carbon frameworks: the hydroxycinnamic and hydroxybenzoic structures. It is a very good antioxidant, naturally found in rice grains, particularly in bran. Pigmented bran generally contains higher amount of phenolic compounds.The presence of these compounds is higher in brown rice, fermented rice and popped rice as compared to other products. The bran layers, present in these products are responsible for higher accumulation of phenolics but in case of fermented rice, the understanding isnot well known. γ-oryzanol and Vitamin-E (tocoferol and tocotrianol) are also reputed for its antioxidative activity. Vitamin E is indispensable for reproduction and prevents diseases associated with oxidative stress, such as cardiovascular disease, cancer, chronic inflammation and neurologic disorders. In brown rice, the vitamin-E content varied between 10.4–32.5 mg/kg. Parboiling affects the retention of vitamin E, which displayed an average loss of approximately 40 to 60% as compared to the initial level. The preparation of puffed rice, flake rice and boiled rice involved hydrothermal processing, which resulted the loss of Vitamin-E. The lowest was obtained from cooked rice (raw) and highest in brown rice. Chemically, γ-oryzanol is the esters of ferulic acid with phytosterols and triterpene alcohols, generally referred as sterylferulates. Brown rice is also a unique source of γ-oryzanol, which is a mixture of at least 10 lipophilic phytosteroids.γ-oryzanol biosynthesis initiates with acetyl-CoA and form isopentenyldiphosphate (IPP) via mevalonic acid through some enzymatic steps.Parboiling followed by storage results in a loss of about 40% of γ-oryzanol content, whereas cooking causes almost no change in their level. Like vitamin-E, γ-oryzanol content in cooked rice (raw) showed lowest while brown rice contains highest amount of this biomolecules. Iron is mostly found in heme proteins. Generally, the amount of available iron in staple food is low due to the presence of phytic acid, which form chelate with minerals. Fe content in grains ranged between 12 to 51 $mgkg^{-1}$ and RDA (Recommended Dietary Allowance) values for females and males are set to 18 and 8 mg/day respectively. Brown rice contains highest Fe but after milling it is drastically reduced (about 60% reduction). However, in popped and fermented rice this mineral can be found in substantial amount. The appropriate mechanism of enhanced concentration of Fe in fermented rice is not well understood. Zn is also an essential element for human nutrition. It serves as a cofactor of the enzyme carbonic anhydrase and other enzymes. Severe zinc deficiency often accompanies vitamin A

deficiency, hypothyroidism, diabetes and lower breast milk. RDA value of Zn for females and males aged 31–50 are 8 and 11 mg/day respectively. Zn content of brown rice is higher than other products but interestingly fermented rice ranked second with respect to Zn retention. The appropriate explanation for higher Zn content in fermented rice is not so clear.

Table 2. Nutritional composition of some other rice products.

Nutritional compounds	Idli[1]	Rice wine[2]	Rice noodles[3a]	Brown Rice Pasta[4]
Starch	75.00 g%	NA	74.19%	NA
Amylose	31.00 g%	NA	25.97%	10.24%
Amylopectin	44.00 g%	NA	NA	NA
Reducing sugar	NA	NA	0.94%	NA
Total carbohydrate	81.60 g%	91.00%	NA	NA
Protein	10.21 g%	9.00%	7.39%	14.46%
Fat	00.10 g%	NA	1.00%	0.68%
Ash	NA	NA	0.89%	1.85%
Crude Fiber	00.28 g%	NA	NA	6.03%
Ethanol	NA	3.00 – 14.00%	NA	NA
Polyphenol	NA	149.0 – 1160.00 mg GAE/L	NA	NA
Antioxidant activity(ABTS)	NA	369.00 -3585.00 mg ascorbateeq/L	NA	NA
Calories	NA	39.00	NA	NA
Solubility	NA	NA	12.39%	NA
Swelling Power	NA	NA	8.89%	NA

**Source: 1.Website: shodhganga.inflibnet.ac.in;2.Cai et al.,2018; 3.Zhu et al., 2019; 4.Wanget al., 2016*

There are several other food products manufactured from rice. Amongst them Idli, Dhosa, Noodles, Pasta, Cake, Wines, *Papad* are very popular in India and other Asian countries (Table 2). Idli is very popular in South India and generally consumed as breakfast food. It is highly nutritious as it contains lower fat and higher amount of protein due to presence of pulses in it. Rice pasta also contains higher amount of protein and substantial amount of crude fiber. Crude fiber is not a nutritional component but used as a laxative compound. Rice wine is not so popular in India but very popular in China, Japan and other countries. It is clear liquid containing 3 to 14% ethanol and very good amount of polyphenols, which acts as an antioxidant.

Sensory analysis of different rice products

Rice is consumed as staple in many countries and consumers have strong preferences for the sensory properties of rice. Different countries have different requirements for quality, and a range of preferences can be found within countries. A wide range of genotypes with different sensory quality are found in all the states of India. Some rice cultivars are the geographical indicator (GI) of that particular region viz. basmati rice can only be grown in northern states of India. Sensory quality refers to different parameters like colour, aroma, texture, taste etc., which are the primary criteria of the consumer's acceptance as a food item. Texture profile analysis (TPA) is an instrumental test originally developed at the General Foods Corporation Technical Centre (1963) toprovide objective measurements of texture parameters, a major factor of food acceptability. The colour parameters of rice and their products are very important for consumers. The colour of grain samples at puffing, popping, boiling and beaten rice were determined by CIE colour scales L*, a* and b* using Hunter Lab digital colourimeter,where L* indicates the degree of lightness or darkness of the sample extended from 0 (black) to 100 (white), a* and b* indicates degree of redness (+a) to greenness (-a) and whereas b* indicates the degree of yellowness (+b) to blueness (-b), respectively.

Szczesniak (1963) and Brandt et al., (1963) grouped the textural properties as initial (on first bite: hardness, viscosity, brittleness), masticatory (during chewing: gumminess, chewiness, adhesiveness) and residual (rate of breakdown, type of breakdown). The cooking methods significantly affect the textural properties of cooked rice while the effect depends on the rice types and method of processing. Generally, rice must be cooked prior to consumption. The amylose content of rice is deemed as one of the most important factors influencing the cooking characteristics of rice (Delwiche et al., 1995). On the basis of amylose content, Juliano (1992) categorized rice to five groups such as waxy (0 to 5% amylose), very low (5 to 12% amylose), low (12 to 20% amylose), intermediate (20 to 25% amylose) and high (25 to 33% amylose)

amylose rice. After cooking, the rice with high amylose content would be dry, less tender and become hard on cooling. By contrast, low-amylose rice after cooking becomes moist and sticky (Mutters and Thompson, 2009). Apart from the amylose content of rice, Roy et al. (2010) pointed out that the cooking properties of rice depends on the forms of rice, the water-rice ratio and the preset cooking mode. It is well known that the brown rice requires much longer cooking time and water-rice ratio than white rice, which makes brown rice inconvenient and not compatible with the modern lifestyle. Sensory analysis can be done by a semi-trained sensory panel using a quantitative descriptive analysis (QDA).Preparation of puffed rice requires double parboiling, which leads to changes in textural and chemical properties. Juliano et al. (1987) reported that the hardness of puffed rice depends on amylose content of the grain, pressure and time of parboiling and ranged between 0.16 to 1.96 kg. Cooked grains of Basmati-370 showed highest cohesiveness, chewiness, and maximum force and hardness values among three popular rice varieties such as Basmati- 370, IR-8 and PR-106. The translucent rice kernels of these three varieties showed hardness values of 58.22, 25.82 and 20.63 N/mm, respectively. The textural analysis revealed that translucent cooked grains had higher cohesiveness, chewiness, maximum force and hardness values than chalky cooked grains.The grains with high amylose had hard texture and required less cooking time (Singh et al., 2003).

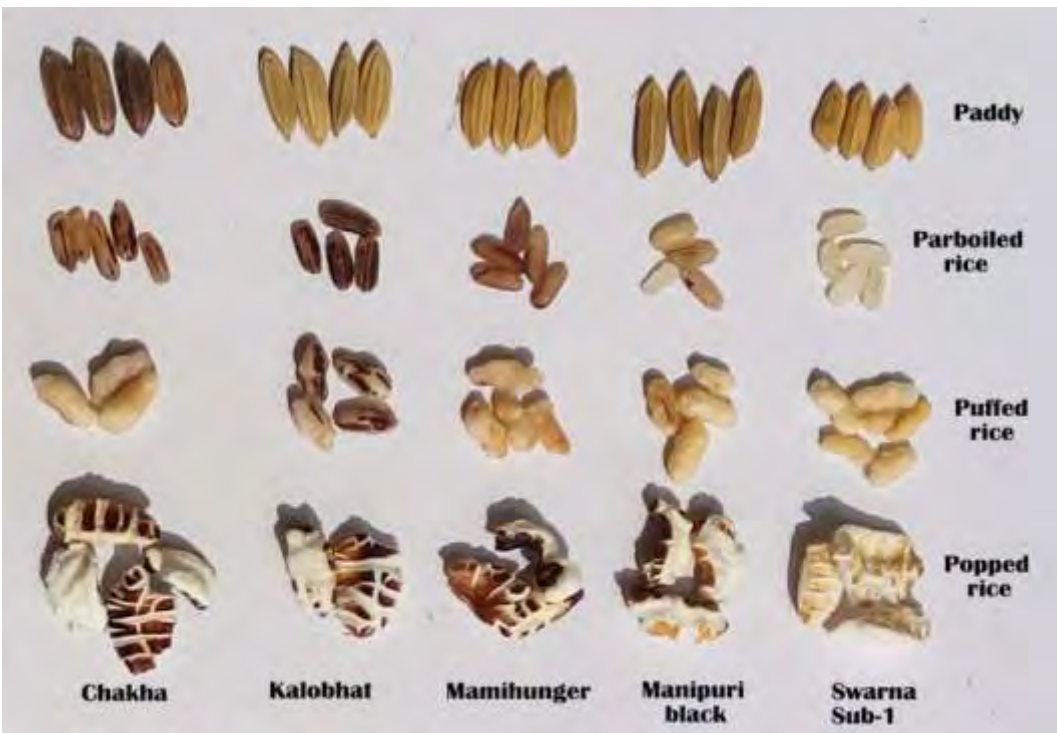


Fig. 2: Processed products of some pigmented rice.
Source: Pal et al. (2019)

Traditional rice products and their nutritional values

Rice is being utilised since long time for preparation of some traditional dishes. In India, state or region wise, the rice products are unique with respect to ingredients, method of preparation and sensory quality. Historically, Indian women are having expertise to prepare these products. The method of preparation with recipe are well documented by Das (2015). However, the nutritional profiling of these products is not well known. As these products are very popular in major parts of the country, research regarding nutritional aspects as well as sensory attributes are very essential.

Table 3.Common names of some the rice products in different states of India.

Sal. No.	Name of some ethnicrice products	States of popularisation
1	*ArishaPitha, Attakali, BudhaChakuli, ChakuliPitha, ChhunchiPatraPitha, ChudaGasha, HaldiPatraPitha, KankraPitha, KhiraPodaPitha, PodaPitha, SaruChakuli*	Odisha
2	*GurerPayesh, Khuchuri, Pattisafta, PuliPitha, GokulPitha, Joynagerer Moan, Sara Pitha,MugerPuli, Chital pitha, ChirerMoan,PanPitha*	West Bengal
3	*Kasar, Rasia*	Bihar
4	*Angakar Roti, Chila, Chusela, Dehrori, Fara*	Chattishgarh
5	*Kharzi, Khura*	Arunachal Pradesh
6	*AanguliPitha, GhilaPitha, PithagurirHalwa, TilPitha, XutuliPitha*	Assam
7	*Jadoh, Putharo*	Meghalaya
8	*Kashmiri Polao, MudurPulao, Phirni*	Jummu and Kashmir
9	*JaipuriMewaPulao,*	Rajasthan
10	*KesariMishthan, Tehri,*	Uttar Pradesh
11	*Akki Roti, Belladanna,Chitranna, Kodubale, Rice Burfi*	Karnataka
12	*Akkaravadisal, Coconut Sevai, Idli, Masala Dosa, Pongal,ThayirSadam,*	Tamil Nadu
13	*Andhra Pulihora, BellamUndrallu, Coconut rice, Biryani*	Andhra Pradesh
14	*Idiyappam, Kallappam, Puttu, Unniappam*	Kerala
15	*DoodhPaak, BardolikiKhichdi, Gujarati Dhokla, KhamanDhokla, Khichu*	Gujarat

Source: Das(2015)

Though these ethnic, value-added rice products are being prepared from many ingredients, which are consumed commonly, the nutritional change after making final products are not known adequately. The raw materials of these products contain different forms of rice grain and many other ingredients such as milk, sugar, pulses, oil, coconut, cashew nut, raisins, different spices and condiments, jaggery, wheat flour, corn flour and different vegetables or non-vegetables items. Therefore, the nutritional composition and human digestibility are varied according to the recipe and processing methods.

Nutritional composition of rice bran oil

Rice bran is the upper thin layers of white endosperm of rice grain. It can be obtained as a bi -product of rice milling and contains 14 to 15% crude oil. The extraction of the oil can be done simply by solvent extraction or pressing by a machine. Rice bran oil (RBO), one of the high-valued edible vegetable oils recommended by WHO, is widely consumed in the major parts of the Asian countries. It contains large amounts of unsaturated fatty acids (oleic acid and linoleic acid) and many dietary phytochemicals such as vitamin-E,squalene, phytosterols, polyphenols, and γ-oryzanol. These bioactive compounds show excellent physiological activities and can be used as an antioxidant, anti-inflammatory agent, and for the treatment of cardiovascular disease. Oleic acid (C18:1) was found at the highest levels in the RBO, followed by linoleic acid (C18:2), and palmitic acid (C16:0). It also contains substantial amount of PUFA (Poly unsaturated fatty acids), which is beneficial for the health of heart.An imbalance of omega-6 and omega-3 PUFAs in the diet is associated with an increased risk of cardiovascular disease. The optimal dietary ratio of omega-6 to omega-3 PUFAs is between 1:1 and 4:1. As leafy vegetables and fish oil are rich in EPA eicosapentaenoic acid and DHA (docosahexaenoic acid), these are often prescribed for individuals with a history of cardiovascular disease. Acid value (AV) and peroxide value (PV) are also the most basic andimportant physicochemical parameters to assess the quality or edibility of oil. The AV of the rice bran oil is low after refining, which is within the permitted levels of Codex Stan 210–1999 Codex Standard for Named Vegetable Oils ($\leqslant$ 0.6 mg $KOHg^{-1}$). In addition, it also exhibits the acceptable PV level (approx. 1.17 $mmolkg^{-1}$) after refining(prescribed level $\leqslant$ 10.0 $mmolkg^{-1}$). However, it is recommended that RBO mixing with other edible oil are better for health. Blending of RBO with sunflower oil (70:30 v/v) exhibits better antioxidant property than any single oil (Choudharyet al., 2015).

Table 4: Comparison of fatty acid and nutritional composition of rice bran oil with other oils commonly used.

Sl. No.	Fatty acids	Chemical composition(%)	RBO	Mustard oil	Sunflower oil
1	14:00	Myristic acid	0.1-0.3	-	0.1
2	16:00	Palmitic acid	12.8-21.6	10.24	6.0-7.1
3	18:00	Stearic acid	0.7-4.7	2.02	2.5-4.1
4	20:00	Arachidic acid	0.5-1.4	0.92	-
5	16:01	Palmitoleic acid	0.0-0.3	-	-
6	18:01	Oleic acid	32.4-43.4	36.65	23.1
7	18:02	Linoleic acid	28.0-53.4	22.06	65.1
8	18:03	α-Linolenic acid (ω-3)	0.2-1.6	8.06	0.2
9		Free Fatty acids	0.29-0.55	0.43	0.04-0.08
10		Oryzanol	0.55-1.39	-	-
11		Tocopherol(mg%)	48.0-70.0	21	50.0-52.0
12		Total PUFA	37	21	65.7
13		Total MUFA	38	60	19.5

- Source:Gopala Krishna et al.(2006)
- PUFAs (Poly Unsaturated Fatty Acids) with a double bond between C-3 and C-4 (from methyl end of fatty acid chain) are called omega-3 (ω-3) fatty acids, and those with a double bond between C-6 and C-7 are omega-6 (ω-6) fatty acids.

Table 5: Quantification of antioxidants of some pigmented rice by-products.

Pigmented rice products /by-productsAntioxidants			Reference	
1	Waxy boiled black rice (*Oryzastiva*L. Indica)	China	Phenolics(Raw)- 4.92 mg GAE/g Flavonoids(Raw)-2.81 mg CAE/g Phenolics(boiled)- 3.79 mg GAE/g Flavonoids(Boiled)-2.42 mg CAE/g	Tang et al.(2015)
2	Nonwaxy boiled black rice (*Oryzastiva* L. Indica)	China	Phenolics(Raw)- 6.97 mg GAE/g Flavonoids(Raw)-3.91 mg CAE/g Phenolics(boiled)- 5.11 mg GAE/g Flavonoids(Boiled)-3.10 mg CAE/g	Tang et al.(2015)
3	Black rice bran (Shinmyongheugchalbyeo)	Korea	Protocatechuic acid-4.6 to 8.3 µg/g *p*-Hydroxybenzoic acid -2.1 to7.3 µg/g Gallic acid -0.6 to 13.5 µg/g Vanillic acid-5.1 to 28.4 µg/g Syringic acid -0.4 to 10.1 µg/g *p*-Coumaric acid -9.5 to 50.0 µg/g Ferulic acid -20.3 to 178.3 µg/g Sinapic acid-3.9 to 9.6 µg/g	Jun et al.(2015)
4	Black rice bran (Taibalang black waxy rice)	Tiwan	*Free:* Protocatechuic acid -100 to 176 µg/g p-Hydroxybenzoic acid -3 to 7 µg/g Vanillic acid -45 to 719 µg/g p-Coumaric acid -9 to 12 µg/g Ferulic acid -36 to 45 µg/g Sinapic acid-ND *Bound:* Protocatechuic acid -948 to 1043 µg/g p-Hydroxybenzoic acid -30 to 34 µg/g Vanillic acid -335 to 652 µg/g p-Coumaric acid -140 to 232 µg/g Ferulic acid-1295 to 1601 µg/g Sinapic acid-62 to 80 µg/g	Huang et al.(2016)
5	*Black rice Bran of the following cultivars:*Heizhenzhu Heixian 3 Longjin 01 Qindao 2 Heijing 72 Heiyounian 97 Heifengnuo Heisuai Heinianmi 5 Heijing 04 Yunxiangnuo Heinuo 9933	China	Free phenolics-20.86 to 70.43 mg GAE/g. Bound phenolics-2.21 to 3.82 mgGAE/g Total flavonoids-35.96 to 124.48 mg CE/g Total anthocyanin-12.31 to 51.01 mg CE/g Cyanidin-3-Glu-7.36 to 25.57mg/g Cyanidine-3-Rut-0.22 to 0.95mg/g Peonidine-3-Glu-1.00 to 5.34mg/g	Zhang et al.(2010)

6	KhaoNim (Boiled rice)	Thailand	Total Phenolics: Raw: 4.99 mg GAE/g Cooked: 5.42mgGAE/g	Melini et al.(2017)
7	*Oryzasativa*L. *japonica*var. SBR (Boiled rice)	California, USA	Protocatechuic acid: 120.44(Raw) 395.64 (Boiled)µg/g Cyanidin-3-glucoside: 572.47(Raw) 147.62(Boiled) µg/g Peonidin-3-glucoside: 29.78(Raw) 10.93(Boiled) µg/g Total anthocyanin:618(Raw), 186 (Boiled) µg/g	Hiemori et al. (2009)
8	Rice grain of cv.Venere	Italy	Protocatechuic acid-77.4 (raw)- 45.4 (boiled) µg/g m-Coumaric acid -175.1(raw) -52.1(boiled) p-Coumaric acid -35.9 (raw)-25.9(boiled) µg/g Ferulic acid-188.2 (raw)-206.3 (boiled) µg/g Diferulic acid-23329(raw) to 17775 (boiled) µg/g Triferulic acid-8946(raw)- 6712(boiled) µg/g	Zaupa et al.(2015)

National and international status of other food products of rice

Across Asia, many sweet and savoury rice-flour-based cakes and dumplings are generally available as snack-foods from markets. Glutinous rice (or waxy rice) flour is commonly used to make many of these products, including Japanese *mochi* and Indonesian layered rice cakes (kuelapis), which require a sticky texture. Alcoholic beverages made from rice are found throughout the rice-producing world. In Philippines, the most common is a rice beer/wine produced by boiling husked rice with yeast cake and allowing the mixture to ferment for a short period. Rice vinegar in China and Japan, rice milk in US and Thailand, Rice syrup (liquid glucose) in many Asian countries are very popular. Canned rice products and quick-cooking packaged rice are found in many countries. Various types of packaged quick cooking or 'instant' rice meals or side-dishes, are also available internationally. Rice starch is used as thickening agent in many food products. Wild rice stem is consumed as vegetables in China and other Asian countries. Some rice flour based products are very popular in African countries. Pan cake, Rice biscuit, Rice candy, Bread, Instant rice porridge and noodles are mostly consumed in Nigeria and other African countries. Rice grain contains many antioxidant compounds that enhance the quality of hair and skin. Several countries are now making cosmetics, liquid soaps, face washes, and hair products from rice, including Japan, Korea, Philippines and Thailand.

Table 6: Rice genotypesand land races suitable for making different products in India.

Sl.No.	Products	Amylose content (%)	Protein content(%)	Name of cultivars/Landraces
1	Boiled rice	>20	NA	Swarna, Naveen, Satabdi, Pooja, Lalat,Banskathi, Tulaipanji,
2	Popped rice	<20	NA	JP-73, Kabirajsal, Dehradun,Gandheswari, Kanakchur, Lalkhasa, Lotishail, Lalbinni,Dulon, Binni
3	Puffed rice	Intermediate	Low	Lalat, Jaya,Swarna, KHP-2, IET-13901,Intan, Rajeshwari, Sempalai, TRY1, Mahamaya
4	Flaked rice	>20	NA	TRY 1, Samba Mozsanam,Pisini, Rajeshwari,MahamayaMoina, Shaila, Chonshoni,Jotibalam, Tulini, Kheyai,Shilkomor, Binnaful, Paitonga,
5	Idli/Dhosa	22 to 26	Low	Samba Mozsanam, Kudaivazhai, KappakarErunkar, IR-8, Savitri,
6	Rice wine	<15	NA	NA
7	Rice noodles	>23,Low GT	NA	Taichung Native 1
8	Rice Pasta	>23	NA	Taichung Native 1
9	Rice cake	20 to 25	NA	Kalamota, SadaKajol, Chapa mota, TopaAman, Lalmocha, Karti, Kartikshail, Boali, Jiadhan, Dudhkotki,Talrodha, Ajoldigha,
10	Biriyani	>25	NA	Pusa basmati 370, Tarori Basmati
11	Sweets	<20	NA	Gobindabhog, Nuakalajeera, Nuachinikamini, Radhunipagol, Sivappuchitraikar
12	Joynagarer Moan	21 to 22	NA	Kanakchur (popped rice)

Some anti-nutritional factors in rice

Anti-nutritional factors are the bio molecules which have detrimental effects to humans and animal growth by impairing uptake or utilization of other foods and feed components or generate discomfort and stress. It is mainly occurred in pulse but rice grains have some anti-nutritional factors mainly concentrated in bran layers viz. Phytic acid, alpha amylase inhibitor, trypsin inhibitor, polyphenols, toxic chemicals, heavy

metals and arsenic. Phytic acid (PA), known as *myo*-inositol 1,2,3,4,5,6- hexa-*kis*-phosphate, often exists in the form of a mixed salt (phytate or phytin) of mineral cations, including Zn^{2+}, Ca^{2+} and Fe^{3+}. It reduces the bioavailability of minerals in our intestine due to formation of complex. Phytic acid digestive enzyme (Phytase) is absent in our intestine. It also reduces the activity of protein and starch digestive enzymes in our digestive tract. In raw rice grain the range of phytic acid varied between 0.1 to 3.0 % depending on genotypes. However, in some cases phytic acid acts as an antioxidants, anticancerous and hypoglycaemic agent but the threshold level of phytic acid content in rice grain for our consumption, is not established clearly. In some study, it was shown that phytic content of rice was reduced after different hydro-thermal processing of the grains. Alpha-amylase and trypsin inhibitor are the agents which impair the activity of digestive enzymes for carbohydrate and protein and it was observed that their content in rice is lower than wheat and pulses. Polyphenols are the compounds which generally act as antioxidants but sometimes in higher concentration, it is responsible for generating imbalance in proton gradient generated in mitochondrial electron transport chain resulting disturbance in ATP formation. Therefore, it may acts as an anti-nutritional factor. In rice, total phenol content ranged between 100 to 1500 mg GAE/100g depending on genotypes and environmental factors for rice cultivation.Heavy metals like Mercury, Cadmium, Chromium, and Lead are toxic metals and their accumulation in our bodycancause serious effects like anaemia, hypertension and kidneys, lungs, bones problem. Arsenic is the metalloid and contaminates the ground water of intensive rice growing area. According to FAO, the allowable limit for Mercury, Cadmium, Lead and Arsenic in rice grain is 0.1, 0.1,0.2 and 0.2µg/g respectively. Rice grain may be contaminated with some fungal toxins like aflatoxin and many pesticides but the possibility of its occurrence is very less.

Conclusion

The bulletin provides information on chemical compositions of rice products. The information may be valuable especially for rice growers and consumers. Rice protein is hypoallergenic, gluten free and easy to digest. Rice bran oil is also very healthy as it contains unsaturated fatty acids, vitamin-E and gamma oryzanol. Rice starch contains amylose (1 to 30%) and amylopectin (50 to 70%). However, all the cooking and product making properties depends on properties of starch and protein in rice grains. Therefore, all the rice products can be consumed according to the preference and health condition of the people. Now-a-days, high protein rice and pigmented rice are gaining attention to the consumers due to their health promoting factors and therefore, in future, their products will also become popular gradually.

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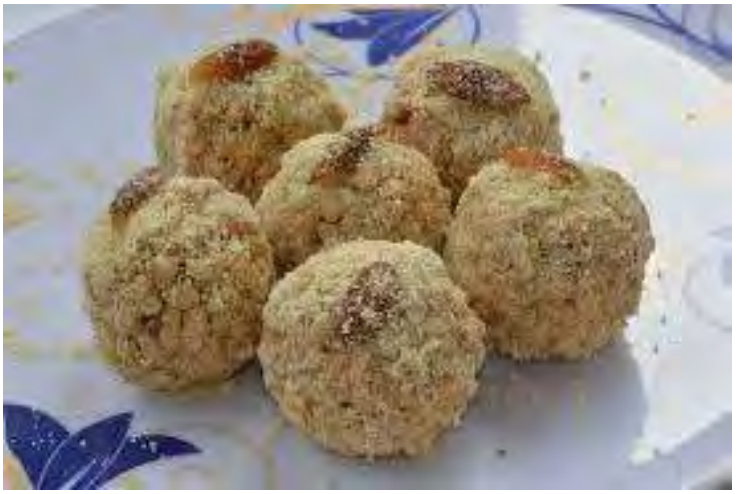


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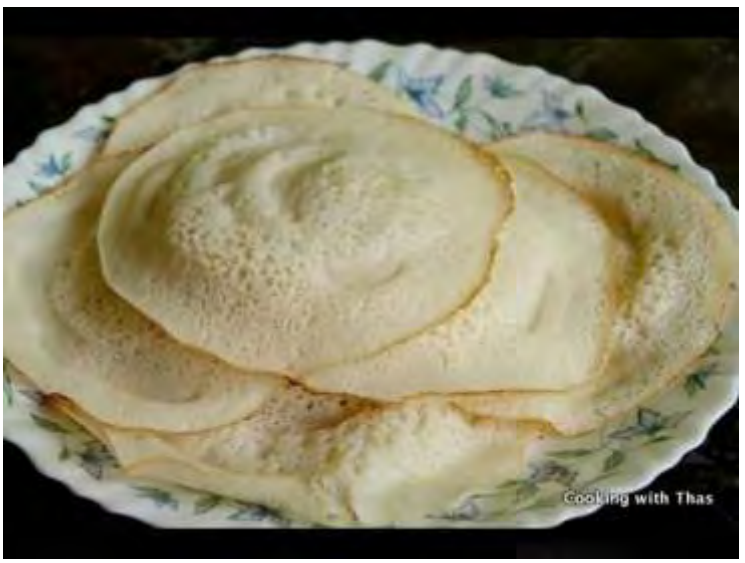
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