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Health Benefits of Rice Bran - A Review

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Abstract

Rice bran along with the germ is an inherent part of whole grain which consists of phytonutrients like oryzanols, tocopherols, tocotrienols, phytosterols and importantly dietary fibers. The complete exploitation of its potential has not been realized due to problems associated with rancidity. However, owing to numerous stabilization procedures, it has been possible to derive an array of health-promoting value-added products. The applications span over a wide range starting from cholesterol reduction, combating cancer, alleviating menopausal and postmenopausal symptoms, masking the signs of ageing to production of PHA substitutes and treating water from agricultural run-off. The most commonly used form is its oil that has exceptional properties which makes it unparalleled when compared with other vegetable oils. This article gives a bird's eye view of rice bran and its distinct properties.

Keywords: Rice bran; rice bran oil; gamma oryzanol; phytosterols; hypocholesterolemic

Introduction

Rice is the most important cereal product in Asia and is an overwhelming staple food in most populations of this region [1,2]. It is grown in more than 100 countries and there are around 18,000 varieties accounting for about 25% of the world's food grain production [3]. The prominent rice producing continents are Asia, Africa and America [4]. Milling of paddy yields 70% of rice (endosperm) as the major product and by - products consisting of 20% rice husk, 8% rice bran and 2% rice germ [1,4-6]

The brownish portion of rice which is taken out in fine grain form during de-husking and milling of paddy is the rice bran [3,7]. The bran is the hard outer layer of rice consisting of aleurone and pericarp. Rice bran contains an array of micronutrients like oryzanols, tocopherols, tocotrienols, phytosterols, 20% oil and 15% protein, 50% carbohydrate (majorly starch) dietary fibers like beta-glucan, pectin, and gum[3,8-10].

Rice bran, which was earlier used primarily as animal feed, is now finding major application in the form of rice bran oil [1,11,12]. India and Thailand have been the most successful countries in rice bran oil production[1]. In India the solvent extraction process of 40 lakh tons rice bran yields about 6.5 lakh tons of rice bran oil [4]. Rice bran oil refining industry produces residues such as wax sludge, gum sludge and soap stock that are a rich source of many nutraceuticals like oryzanols, tocopherols, tocotrienols, ferulic acid, phytic acid, lecithin, inositol and wax [4,13,14]. Though Japan contributes just 2% of total production of paddy in the world, it is a promising producer of nutraceuticals and other high value products from the derivatives of paddy [13]. The rice bran obtained from different varieties of colored rice are rice in antioxidant compounds *viz* polyphenols, carotenoids, vitamin-E and tocotrienol which help in preventing the damage of body tissue and oxidative damage of DNA [123]. As Ling et al. [124,125] study done reveals feeding bran fractions of certain colored rice varieties to rabbits improved antioxidant status in their blood and showed significant reduction in atherosclerotic plaque.

Stabilizing rice bran

Until recently, rice bran as a source of value-added food product was under-utilized due to lipase enzyme which is endogenously present or produced as a result of microbial activity which is activated during the milling process [15]. These lipases hydrolyze the oil into glycerol and free fatty acids which give the product a rancid smell and bitter taste that renders the bran unsuitable for consumption. Under normal milling conditions rice bran will degrade in approximately six hours into an unpalatable material making it unsuitable as human food. Because of the problem with rancidity, most rice bran is used as a high protein feed additive for animals or as fertilizer or fuel [16]. Since oxidative changes affect the oil quality adversely and are not very rapid in their manifestation, stabilization becomes a pre-requisite. These efforts are aimed at destruction or inhibition of lipase–the enzyme that causes development of free fatty acid (FFA). This is done so as to reduce oil losses which are directly proportional to the FFA content [17]. Rice bran can be stabilized by a variety of methods like cold storage, sun-drying, steaming and expelling. Chemical stabilizers like sodium metabisulphate can also be used. Properly processed extrusion-stabilized rice bran from rough rice can be safely stored for up to one year at ≤22°C in gas-permeable packaging. But the maximum safe storage life for par-boiled rice bran is estimated at less than 3-4 months [4,17].

A promising method of stabilizing rice bran is ohmic heating [18,19]. The passage of alternating current through a food sample results in ohmic or electrical heating by virtue of the sample's electrical resistance [20,21]. In order to stabilize rice bran and improve the oil extraction yield Lakkakula et al. [18], used ohmic heating, the results of which showed that, this is an effective method for bran stabilization when coupled with moisture addition. The concentration of FFA increased at a slower rate with no corresponding temperature rise, indicating the non thermal effect of electricity on lipase activity. The total percentage of lipids extracted were a maximum of 92%.

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The latest invention in this respect has been the use of an acid having antioxidative properties. This is added to food product containing parboiled rice bran in amounts of about 0.10% to 2.0% by weight to maintain the stability of the food product for at least six months at ambient conditions. Examples of these kinds of acids are ascorbic, ascorbyl palmitate and phosphoric acid and mixtures of any of the above. Other examples include acacetin and rosmarinic acid, and phenolic compounds such as salicylic, cinnamic and trans-cinnamic, synaptic, chlorogenic, quimic, ferulic, gallic, p-coumaric, vanillic acid and vanillian, and caffeic acids. However, an antioxidant mixture such as "Petox" (a combination of BHA, BHT and citric acids) has been found to be ineffective when used alone [18-20].

Extraction and refining of rice bran oil

Crude rice bran oil is composed of 4% unsaponifiables, 2-4% free fatty acids and 88-89% neutral lipids. The unsaponifiable fraction is a complex mixture of naturally occurring antioxidant compounds such as vitamin E and oryzanol [4]. For the commercial extraction of oil from rice bran, hexane is the solvent of choice [22,23]. Hexane is directly mixed with stabilized rice bran at 20°C at 2:1 (W/W solvent to bran ratio) or pre-heated to 60°C at 3:1 (W/W solvent to bran ratio) in flasks capped and immersed in a constant-temperature water bath at 40°C or 60°C for pre-determined time. Vaccum evaporation of solvent from the miscella yields crude rice bran oil.

However, hexane poses several drawbacks such as potential fire, health and environmental hazards. For this purpose short chain–alcohols such as ethanol and isopropanol have been proposed alternatively owing to their greater safety and lower need for regulation [24]. Alcohols extract more non-glyceride materials due to their greater polarity. Generally alcohol-extracted oils have greater amounts of phosphatide and unsaponifiable compounds [25,26]. Ethanol has been used for the extraction of rice bran oil rich in tocopherols and B vitamins whereas isopropanol has been used for the extraction of rice bran oil rich in B vitamins alone [10,27].

Though widely accepted, extraction with hexane achieves limited success in terms of good colour quality, by limiting FFA content. This is due to the fact that specific group components of oil seed lipids cannot be controlled. Supercritical fluid has more versatile solvent properties as against liquid extraction agents [28]. This can be attributed to greater control over lipid solubility and mass transfer properties such as diffusivity of the extraction medium. The regulation of these properties is expanded to the entire domain of pressure and temperature above the critical point of SCF being used [29]. RBO yield with SC-CO_2 ranged between 19.2% & 20.4% and the yield increased with temperature at isobaric conditions [30]. In spite of obvious advantages, this technology has limitations due to the high cost of equipment for extraction [13, 31-34].

Introduction of one or two enzymatic reactions prior to solvent extraction resulted in higher oil yields [35-38]. However when these enzymatic treatments were used alone the process did not result in reasonable oil extraction yields [3,39]. Rice bran was treated with cellulase and pectinase and extracted with n-hexane. The effect of enzyme concentration was the most important factor for determining oil and protein extraction yields whereas incubation time and temperature had no significant effect [39]. An alternative enzymatic reaction is the use of alpha-amylase to gelatinize starch prior to a saccharifying step, while the residual paste containing 66.75% of the original bran may be subjected to a proteolytic process for the extraction of proteins or directly treated with solvents to obtain RBO [40].

The oil from the rice bran is stable and fit for consumption after refining. The capacity of present continuous type rice bran oil mill is 50-200 t/d and that of batch type mill is 30 t/d. The refining of RBO improves the quality of edible oil and is economical and gives byproducts like oryzanol, inositol, phytosterols which are of pharmaceutical importance. It minimizes the problems of liquid waste and conserves energy [7,14].

Chemical refining

Conventionally, chemical refining is preferred over physical refining. The RBO has a variety of minor components such as gamma oryzanol, tocopherols, tocotrienols and phytosterols which differ in their composition and renders RBO refining more complicated when compared with the refining of other oils [1,8,13,42]. Some stages in the chemical refining of RBO cause significant losses or changes in the composition of these minor components [1,13]. For instance, the oryzanol content for physically refined RBO was the original amount *i.e.* from 1.1%-1.74% whereas for chemically refined oil it was a considerably lower amount i.e. 0.19%-0.20 % [43]. When the effect of chemical refining was examined on the micronutrients, it showed that alkali treatment results in significant loss of gamma oryzanol and modifies the composition of phytosterols. Bleaching shows formation of some isomers of 24-methylenecycloartanol (a gamma oryzanol component). During deodorization the highly volatile compounds like phytosterols and tocotrienols are stripped off while the non volatile gamma oryzanol is retained that leads to formation of less than 1% trans FA. The entire process of chemical refining removes 99.5% of the free fatty acid component [1].

Physical refining

The physical method of refining RBO is appealing because of its simplicity, lack of environmental impact, low oil losses and good quality product. The recovery of unsaponifiables is more in this method than in chemical refining. Physical refining reduces neutral oil losses and eliminates soap stock by removing FFA. The existence of wax, oryzanol and phosphatides leads to darkening of colour and higher refining losses of RBO. Removal of undesirable components incompletely during pre-treatments affects the quality of the final product [44].

Uses of rice bran

Rice bran has several unique properties that render its suitability for niche markets like nutraceutical and pharmaceutical industry. One such feature is the presence of significant levels of minor-elements such as oryzanol, tocotrienol and phytosterols that have a large nutraceutical application. They are used in the development of value-added healthy products [4]. Gamma oryzanol has been found to have higher anti-oxidant action in comparison with tocopherol. Gamma oryzanol comprises of ferulic acid esters of sterols and triterpene alcohols. The ferulic acid esters are campesterol, stigmasterol, and beta-cytosterol and the triterpene alcohols are cycloartenol, cycloartanol, 24-methylenecycloartanol and cyclobranol [45,46]. Due to its antioxidant action, it is drawing immense interest in research world as a food additive. It has been cited as 'oxidation inhibitor' in the 'food additive list' [5,10,42].

Antioxidant property

The antioxidants at cellular and molecular levels are known to deactivate the natural by-products of the oxidative metabolism that are popularly known as free radicals [13,47,48]. The minor components of the rice bran *i.e.* gamma oryzanol, phytosterols and other phytosterol conjugates are examined to have antioxidant property against the free radicals [49,50]. The ferulic acid ester of the gamma oryzanol is known to be a potent antioxidant which has stabilizing properties at elevated temperatures [51]. Studies have shown that one test tube of gamma oryzanol is four times as effective as vitamin E in inhibiting the cellular oxidation. When compared with the four vitamin E components (alpha-tocopherol, beta-tocopherol, alpha-tocotrienol and beta-tocotrienol) the components of gamma oryzanol showed higher antioxidant capacities. All these factors can be used to develop nutraceuticals and other food ingredients from the chemically suitable and biologically functional compounds of the rice bran that are known to have antioxidant properties [13,49,52-54].

Rice bran in food products

Rice bran is highly nutritious and hence used as a food additive [55]. Its major use as an additive in foods is due to the dietary fibers present in it which confer upon it the properties of a good laxative [56-59]. Sekhon et al. [56], carried out studies which revealed that the bread volume and cookie spread decreased but muffin volume increased with the addition of different types of bran. Interestingly, the addition of full fat rice bran did not affect the cookie spread factor. Different food products could be produced to contain 5-10% rice bran. Similar studies were carried out by Dimitra and Constantina [60-63], to examine the effect of dietary fiber and the bran of various cereals like wheat, oat and rice on cake batter, product shelf life, final cake quality parameters such as batter viscosity, specific volume, porosity and crumb moisture content.

Food grade wax

Wax is an ester of long chain carboxylic acid and a long chain alcohol. During RBO extraction a certain amount of wax is obtained by the dewaxing step of refining process and the amount varies with conditions of extraction like source and history of rice bran, solvent used and extraction temperature [64]. Rice bran wax (RBW) can be distinguished as hard wax (38.5%) and soft wax (11.2%) [65,66]. The presence of resinous matter is majorly responsible for the dark reddish brown colour and characteristic odour of crude RBW [67]. Shaik Ramjan Vali et al. [68] have outlined a process for purifying crude wax and the successive preparation of food grade RBW. The potential applications of RBW can be realized in pharmaceutical, food, cosmetic, polymer and leather industries [69,70].

Poly Hydroxy Alkanoates (PHA)

PHA are the environment–friendly analogues of petrochemical derived plastics which show gas barrier properties comparable to those of poly vinyl chloride and poly ethylene terephthalate [71,72]. In a study conducted by Ting-Yen Huang et al. [73], extruded rice bran and extruded corn starch were used in various proportions as the carbon source by an archae *Haloferax mediterranei* for procuring PHA. By varying the culture conditions, various concentrations of PHA were obtained [74].

The applications of PHA are in manufacture of paper, card board or food trays or as an alternative to aluminium films and polyethylene [74]. Other thrust research areas are controlled drug release, sutures, wound dressing, bone plates, paramedical disposables and therapeutic devices [73].

Medical uses

Stabilized rice bran contains large concentrations of several compounds and has the potential to prevent a range of chronic diseases. It is believed that RB serves as an important functional food that has cholesterol lowering properties, cardiovascular health benefits and anti-tumor activity [10,75].

Lowering cholesterol

RBO have hypocholesterolemic influence resulting from selective decrease of Low Density Lipoprotein (LDL) Cholesterol (C) fraction. This effect was far greater than the predicted values (Table 1). This discrepancy could be attributed to the presence of high concentration of unsaponifiables including phytosterols, oryzanols, and tocotrienols [10,75-77]. Phytosterols have purported to be cholesterol-lowering agents since the 1950s. Most studies undertaken thus far have focused on the action of beta-sitosterol and sitostanol in reducing LDL and circulating cholesterol levels. These results indicate that these agents may be hypolipidemic agents in mild hypercholesterolemia by altering the lipid metabolism, for instance reducing liver acetyl Co-A carboxylase and malic acid activities [78-80]. Gamma- oryzanol was also found to have similar hypocholesterolemic effects. Low and high gamma-oryzanol containing RBO feeding for four weeks reduced total plasma cholesterol (6.3%), LDL-C (10.5%), and LDL-C/HDL-C ratio (18.9%) [81]. Also the unsaponifiables present in the rice bran were shown to significantly reduce liver cholesterol levels [82-84].

Coronary heart disease (CHD)

The consumption of dietary fiber that is present in cereals have shown to reduce the risk of coronary heart disease (CHD) mortality by reducing blood pressure, lowering blood cholesterol levels and improving insulin sensitivity [85-88]. The risk of CHD mortality was inversely related to the consumption of dietary fiber from cereals or fruits [89-91].

For the assessment of coronary heart diseases, levels of individual circulating cholesterol are considered more important than total cholesterol. LDL is directly associated with the development of cardio vascular diseases, whereas HDL has an inverse relationship [78,92-94]. In human diets, supplementation of soluble sitostanol significantly reduced total circulating cholesterol and LDL levels by 7.5% and 10 % respectively [95,98].

Addition of dietary phytosterols has been found to increase Lecithin – Cholesterol Acyl Transferase (LCAT) levels in blood [78,96-99]. This in turn facilitates the sequestration of cholesterol within the hydrophobic core of HDL cholesterol [100].

Edible Oils	Linolenic Acid %	- Cholesterol Level
Safflower	77.1	-16
Sunflower	61.4	-12
Cottonseed	58.0	0
Soybean	50.2	+3
Sesame	45.9	+2
Corn	43.0	-15
Rice Bran	**36.0**	**-17**
Groundnut	35.0	+5

Table 1: Cholesterol lowering activity of RBO in comparison to other edible oils (Sea Handbook, 2009)[4].

Colorectal cancer

Phytosterols have shown to inhibit tumors induced by chemicals in animals. The production of coprostanol and other neutral sterols and bile acids by colonic micro-flora from dietary cholesterol, have been established as factors in colon carcinogenesis [101]. Secondary bile acid products also aid in the development of colon cancer. Studies have suggested that dietary phytosterols significantly alter the levels of faecal cholesterol, cholesterol breakdown products and bile acids by decreasing the epithelial cell proliferation [102,103]. This may be due to suppression of bacterial metabolism of cholesterol and/or secondary bile acid in the colon and by increase of excretion of cholesterol itself [78,104]. Bingham et al. [105] studied the relationship between dietary fiber consumption and the incidence of colorectal cancer. The amount of dietary fiber consumption gave the relative risk estimates in a set of individuals who were grouped by sex-specific, cohort-wide quintiles and from linear models relating the hazard ratio to fiber consumption expressed as a continuous variable. The results showed that the intake of dietary fiber was inversely related to the occurrence of colorectal cancer. The highest protective effect was shown at the left side of the colon where as the least protective effect was at rectum. The value of the adjusted relative risk for the highest versus lowest quintile of dietary fiber was 0.58 (0.41-0.85). Hence it was interpreted that by approximate doubling of total fiber intake in individuals with low average dietary fiber intake, the risk of large bowel cancer reduced greatly by 40% [106,107].

Anti - Ageing / Cosmetics and Personal Care

The oryzanol component acts as a protective agent against UV light induced lipid peroxidation and hence can be used as a potent sunscreen agent. The ferulic acid and its esters present in gamma oryzanol stimulate hair growth and prevent skin ageing [108,109].

Rice bran contains approximately 500 ppm of tocotrienols [110]. Tocotrienols when applied to the skin penetrate and get absorbed rapidly. Majorly they get accumulated at the strata corneum of the skin and act as the first line of defense with their antioxidant property. They stabilize the free radicals generated in the skin when exposed to oxidative rays. They protect the skin against UV induced skin damage and skin ageing and thus help in skin repair. The efficacy of sunscreens containing compounds that reduce penetration of or absorb ultraviolet radiation is augmented by using tocotrienols in them [108,109,111].

Health benefits

Rice bran oil has shown immunostimulation effects. It is rich in phytosterols, sterolins and gamma-oryzanol, a compound with antioxidant properties which may modulate the immune system [112].The gamma oryzanol of rice bran reduced a prominent amount of elevated serum levels in hypothyroid patients [13]. It is known to have a significant effect on menopause by alleviating the menopausal symptoms like hot flashes [113,114]. It is used as an ergogenic supplement by body builders and athletes [115]. Rice bran fraction derived from driselase treatment prevents high blood pressure, hyperlipidemia, and hyperglycemia. Driselase is an esterase-free commercial plant cell wall-degrading enzyme mixture that is made of cellulase, xylanase, and laminarinase [116]. The derivatives from the stabilized rice bran are rich in beta-sitosterols which inhibit the growth and induce apoptosis in breast cancer cells [117]. The nutraceuticals developed from the soluble and fiber fractions of rice bran control both type I and type II Diabetes Mellitus [118]. Augmenting with rice bran health foods that contain oryzanol, lead to reduced bone loss in women who suffered from postmenopausal osteoporosis [119]. As per the studies done Vander Berg et al. the expensive vitamin sources from animals can be replaced by plant sources. Many colored rice cultivars have a ray of micronutrients including a rich reserve of β-carotene which can be converted to vitamin-A which requires the presence of unsaturated fatty acids which in turn are also present in colored rice cultivars [126].

Other uses

The *ortho*, *meta* and *para* dicholorobenzenes have been employed as insecticides for a number of years. Among these the *para-* isomer has been used on a very large scale against insects and moths infesting clothes, hides, furs and museum specimens. Remarkably, rice bran was found to be an effective adsorbant of *para-* dicholorobenzene in a broad pH range of 1-12. The adsorbtion reaction was Freundlich type. This property of rice bran was attributed to the uptake by the intracellular particles called spherosomes [120-122].

Conclusions

India is the second largest producer of rice and consequently majority of the Indian population is dependent on rice as its staple food. Though the bran is rich in micronutrients like oryzanols, tocopherols, tocotrienols, phytosterols, and dietary fibers like beta-glucan, pectin, and gum, it has been underutilized due to several reasons some of them being ignorance, presence of impurities like arsenic and silica, difficulties due to the presence of free fatty acids. Rice bran has been used to develop many health promoting products which have hypolipidemic, anti-tumor, anti-oxidant, ergogenic and laxative properties. An important consumer product from rice bran is the rice bran oil which is obtained by a series of refining steps that can be categorized as chemical and physical refining. When compared it was found that physical refining retains a greater percentage of phytonutrients. Advanced technologies like super critical fluid extraction can be effectively implemented in developing futuristic nutraceutical and pharmaceutical products to combat the present higher incidence of coronary heart diseases and many other ailments.

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