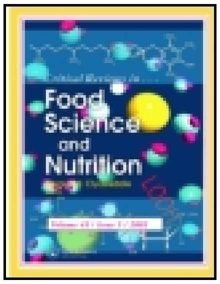

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Rice Bran: A Novel Functional Ingredient

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Rice Bran: A Novel Functional Ingredient

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ABSTRACT

Rice (Oryza sativa) is the most important staple food for a large part of the world's human population, especially in East and South Asia, the Middle East, Latin America, and the West Indies. It provides more than one fifth of the calories consumed worldwide by the human. It is the 2nd leading cereal crop and staple food of half of the world's population. It is grown in at least 114 countries with global production of 645 million tons; share of Asian farmers is about 90% of the total produce. Rice bran, brown outer layer of rice kernel, is mainly comprised of pericarp, aleuron, subaleuron layer and germ. It contains appreciable quantities of nutrients like protein, fat and dietary fiber. Furthermore, it contains substantial amount of minerals like K, Ca, Mg and Fe. Presence of antioxidants like tocopherols, tocotrienols and γ- oryzanol also brighten prospects of rice bran utilization for humans as functional ingredient to mitigate the life threatening disorders. Moreover, in the developing countries, budding dilemma of food crisis, arising due to lower crop yields and escalating population; needs to utilize each pent of available resources. In order to provide enough food to all people, there is the holistic approach of using the by-products generated during food processing and preparations. Rice is being *processed in well established industry but the major apprehension is the utilization of its by-products; rice bran (5-8%) and polishing (2-3%) that are going as waste. Rice processing or milling produces several streams of materials including milled rice, bran and husk. In developing countries, rice bran is considered as a by-product of the milling process and commonly used in animal feed or discarded as a waste. The potential of producing rice bran at the global level is 29.3 million tons annually while the share of Pakistan is worked out to be 0.5 million tons. In present article attempt has been made to highlight the significance of this valuable but neglected ingredients under various heading.*

Keywords rice bran, hypercholesterolemia, hyperglycemia, dietary fiber, rice bran protein isolates, rice bran oil, baked products

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PHYSIOLOGY AND GENERAL CHARACTERISTICS OF RICE BRAN

Rough rice (paddy) is composed of a white starchy rice kernel tightly covered by a coating of bran, enclosed in a tough siliceous hull (Lakkakula et al*.,* 2004). When husk is removed, bran layer comes in direct contact with air, resulting in the development of off-flavor in brown rice due to its endogenous lipase. Moreover, the appearance of brown rice is not appealing due to its color (Saunders, 1990). Hence further processing of rice is required to remove the bran from brown rice to produce white rice (Hu et al*.*, 1996). It is consumed after appropriate polishing to give a desired degree of whiteness (Juliano, 1985). Rice bran constitutes about 10% of the weight of rough rice. It is comprised of pericarp, aleurone, sub-aleurone, seed coat, nucellus along with the germ and a small portion of endosperm (Salunkhe et al*.*, 1992; Hargrove, 1994; Hu et al*.*, 1996). The percentage and composition of rice bran vary according to the rice variety, pretreatment before milling, type of milling system and the degree of milling (Saunders, 1990). Rice bran is light in color, sweet in taste, moderately oily and has a slightly toasted nutty flavor (Hu et al*.*, 1996). Texture varies from a fine, powder-like consistency to a flake, depending on the stabilization process (Barber and Benedito-de, 1980).

TAXONOMIC INFORMATION

Botanical Name	*Oryza sativa*
Kingdom	Plantae
Division	Angiosperms
Class	Monocots

Order	Poales
Family	Poaceae
Genus	Oryza
Species	*O. sativa*

Rice bran contains 12-22% oil, 11-17% protein, 6-14% fiber, 10-15% moisture and 8-17% ash. It is rich in vitamins including vitamin E, thiamin, niacin and minerals like aluminum, calcium, chlorine, iron, magnesium, manganese, phosphorus, potassium, sodium and zinc (Saunders, 1990; Hu et al., 1996; Xu, 1998). Stabilized rice bran of Pakistani rice cultivar "Basmati-385" contains 6.68% moisture, 7.89% ash, 15.78% crude protein, 20.55% crude fat, 7.59% crude fiber and 41.51% nitrogen free extract (Sharif et al., 2005). Rice bran also contains a significant amount of nutraceutical compounds and approximately 4% unsaponifiables, mainly comprised of naturally occurring antioxidant such as tocopherols, tocotrienols and oryzanol (Ju and Vali, 2005). Rice bran proteins are of high nutritional value (Kennedy and Burlingame, 2003) and hypoallergenic (Tsuji et al., 2001). These proteins are rich in essential amino acids, especially lysine, hence can be used as an ingredients in food recipes (Wang et al., 1999). Stabilized rice bran is also a good source of both soluble and insoluble dietary fiber ranging from 20-51% (Saunders, 1990), which is almost twice as much as that of oat bran. Rice bran can be used as a stool bulking agent (Tomlin and Read, 1988) and for the enrichment of some foods (Burton, 2000).

ANTI-NUTRITIONAL FACTORS IN RICE BRAN

The effective utilization of rice bran is possible only by deactivating the lipase enzyme, responsible for the hydrolytic degradation of bran constituents and denaturation of anti-nutritional factors. Successful developments in the use of various techniques to stabilize rice bran have resulted in the emergence of rice bran as an important by-product of the rice milling industry. The anti-nutritional factors in rice bran include lipases, trypsin inhibitor, haemagglutinin-lectin and phytates. Lipases are enzymes that are primarily responsible for the hydrolysis of triglycerides into glycerol and fatty acids. Rice bran contains several types of lipases which results in significant increase of the free fatty acids (FFA) by hydrolyzing the oil. Rapid increase in the free fatty acid occurs within hours and reaches 7-8% within 24 hours, followed by about 5% increase per day (Ramezanzadeh et al*.,* 1999; Rukmani, 2002). Lipase activity is greatly affected by moisture, temperature, pH, time and water activity (Dunford and King, 2001; Gangodavilage, 2002). The enzyme was active upto 40°C and the activity declined sharply to 65% at 60°C and then gradually decreased (Bhardwaj et al*.,* 2001). In addition to native lipases, the microbial lipases also deteriorate the nutritional quality of the oil, making it unfit for human consumption. The hydrolytic rancidity severely affects the nutritive value and palatability of rice bran (Rajeshwara and Prakash, 1995). Trypsin inhibitors are also endogenous enzymes, which can form stable complex with proteolytic pancreatic enzymes i.e. trypsin and chemotropysin. Due to complex formation, the activity of these enzymes decreases. Rice bran contains trypsin inhibitor (Kratzer and Payne, 1977; Deolankar and Singh, 1979). Approximately 85-95% trypsin inhibitor activity was found in rice embryo. One mole of rice bran trypsin inhibitor can inhibit two moles of trypsin.

Haemagglutinin-lectins are toxic globulin proteins present in the rice bran and agglutinate mammalian red blood cells (Ory et al*.,* 1981). Similarly, lectin is a glycoprotein and is present in germ portion. It comprised of 27% carbohydrate, predominantly glucose (Takahashi et al*.,* 1973) while another 10% carbohydrate is mainly in the form of xylose and arabinose (Indravathamma and Seshadri, 1980). The lectin also contains a large number of glycine and cystine residues (Tsuda, 1979). Phytates (1,2,3,4,5,6-hexaphosphate of myoinositol) occur in discrete regions of cereal grains and accounts for 85% of the total phosphorous content of grains. They reduce the bio-availability and digestibility of nutrients by forming complexes with minerals, protein, digestive enzymes and amino acids mainly lysine, methionine, arginine and histidine (Jangbloed et al*.,* 1991; Bird, 1998). It is a rich source of minerals particularly phosphorous, zinc and ferrous (Farrell, 1994). Phytic acid showed strong chelating properties due to its structure (Ramzan, 2000). Phytates also affect the solubility, functionality and digestibility of proteins and carbohydrates.

PROCESSING OF RICE BRAN

The processing of rice bran was carried out to inactivate lipases as well as other nutritional inhibitors in such a way that their toxicity is ruined without damaging the protein quality of rice bran. Furthermore, it also destroys the field fungi, bacteria and insects infestation; ultimately the bran becomes safe from further deterioration which alternately enhanced its shelf life. The greatest restriction to the use of rice bran as a food ingredient is its instability during storage. Upon milling, the oil is exposed to lipases, causing rapid breakdown to free fatty acids @ 5–7% of the weight of oil per day. Hence due to the naturally occurring enzymatic activity and subsequent hydrolytic rancidity, it is necessary to stabilize the rice bran by suitable techniques for controlling undesirable reactions. Bran, after proper stabilization, can serve as a good source of protein, essential fatty acids, calories, and nutrients such as tocopherols and ferulic acid derivatives. The commonly used stabilization techniques are thermal and chemical treatments (Randall et al*.,* 1985; Kim et al*.,* 1987). There are different types of heat stabilization procedures such as retained moisture heating (Lin and Carter, 1973), added moisture heating (Saunders, 1986), extrusion cooking (Sayre et al*.,* 1982), microwave heating (Malekian et al*.,* 2000) and Ohmic or electrical heating (Lakkakula et al*.,* 2004).

Heat stabilization is accomplished commercially by wet or dry heating methods i.e. hot air, drum drying, dry extrusion and microwave (Prabhakar, 1987; Narisullah and Krishnamurthy, 1989). Although hot air drying is an effective method of stabilization, the non-uniform heating of material in the tray driers limits its application. Rice bran was stabilized by fluidized bed drying at 90-130°C (Fernando and Hewavitharana, 1993). Although fluidization provides uniform heating of bran; however, high air velocities are required for the process; making it uneconomical (Narisullah and Krishnamurthy, 1989). The stabilized rice bran was obtained by drum drying at 156ºC (Delahaye et al*.,* 2005). Parboiling also results in stabilization of rice bran by destroying lipase activity (Narisullah and Krishnamurthy, 1989). An edible acid (0.1-2.0% acetic acid) having anti-oxidative properties was added to parboiled rice bran to maintain the stability of the bran for at least 6 months at ambient conditions (Tao, 2001). The common drawbacks in heat treatment methods are: severe processing conditions capable of damaging valuable components, substantial moisture removal and inability to achieve irreversible inactivation of enzyme. To cope with these problems, moist heat treatment is suggested. Extrusion cooking has been found to produce stable rice bran by holding at 125-130 ºC for few seconds, then at 97-99 ºC for 3 minutes prior to cooling (Randall et al., 1985). Heating in the presence of moisture is more effective for permanently denaturing lipases (Ramezanzadeh et al., 1999). Long-term storage studies with extrusion cooking indicate stability against FFA development upto 4 months (Carroll, 1990; Randall et al., 1985), in contrast to dry heat methods. Hence steaming is suitable method of bran pretreatment with respect to decrease in FFA development and the oil extractability in small-scale (Amarasinghe and Gangodavilage, 2004). However, less flexibility and higher initial and operating costs make the process uneconomical. Furthermore, moist heat results in agglomeration of bran, resulting in lumpy bran.

To achieve proper stabilization, every discrete bran particle must have uniform moisture content, depending upon time and temperature. In recent years, use of microwave energy as an inexpensive source of heat for thermal processing of foods has offered an alternative energy source for stabilization of rice bran. It is considered to be one of the most energy-efficient types and a rapid method for heating food items (Yoshida et al., 2003). Considering other heat treatments, microwave heating is efficient, economical, shorter in processing time, minor effects on the nutritional value and has a little or even no effect on the natural color of bran. Microwave heating is an effective method for stabilizing rice bran with the addition of moisture, which enables heating over 100ºC to occur (Malekian et al., 2000). The water molecules in the rice bran are excited to spin by the electromagnetic waves resulting enhanced kinetic energy along with the friction. Since water molecules play an important role in this process, the initial moisture content is a critical factor in the microwave stabilization. Rice bran was stabilized by heating in a microwave for 4 minutes until the internal temperature reached 110-115°C to denature the enzymes (Zhu, 2000).

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DIETARY FIBER OF RICE BRAN

Dietary fiber is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with partial fermentation in the large intestine (CAC, 1998). These are plant food materials that are not hydrolyzed by enzymes secreted by the human digestive tract but may be digested by micro flora in the gut. These plant food materials include non-starch polysaccharides such as celluloses, some hemi-celluloses, gums and pectins as well as resistant starches (DeVries, 2001). The components of dietary fiber include cellulose, hemicellulose, pectins, hydrocolloids and lignin. These can be classified into two major categories depending on their solubility in water. In humans, the structural or matrix fibers (lignins, cellulose, and some hemicelluloses) are insoluble, whereas the natural gel-forming fibers (pectins, gums, mucilages, and the remainder of the hemicelluloses) are soluble. Soluble fiber acts like a gel and insoluble fiber adds bulk or softens stool. Soluble fiber forms a gelatin like substance in the intestine and increases the water content in stool. It has been shown that soluble fiber decreases blood cholesterol and sugar after meals in diabetics (Yeager, 1998). Similarly, insoluble fiber is effective in increasing feeling of fullness, stool size, bulk and helps to reduce constipation and hemorrhoids. Good sources of soluble fibers include fruits, vegetables, legumes, psyllium seeds and oat bran whereas whole grains are good sources of insoluble fiber (Matz, 1991).

Fiber supplementation has been used to enhance the fiber content of array of foods. Traditionally, fiber supplementation has focused on the use of milling by-products of cereal grains like wheat, corn, sorghum and other grains (McKee and Latner, 2000). Nowadays, fiber

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supplementation has focused in cookies, crackers, snack foods, beverages, spices, imitation cheeses, sauces, frozen foods, canned meats, meat analogues and many other cereal-based products (Hesser, 1994). The WHO recommendation for total dietary fiber intake is above 25 g/day (WHO, 2003). The total dietary fiber content in stabilized rice bran ranges from 25 to 40% depending on the product (Carroll, 1990). Rice bran's fiber comprised of a relatively low proportion of soluble fiber (7–13%) and the rest is insoluble fiber (Anderson et al*.,* 1990). However, rice bran has high percentage of oil (12–23%) as compared to other bran sources, with 4.2% unsaponifiable matter (Sugano and Tsuji, 1997). Rice bran oil, possibly because of unsaponifiable fraction or its fatty acid content, lowers cholesterol levels in hamsters, rats, humans and non-human primates (Sharma and Rukmini, 1986; Seetharamaiah and Chandrasekhara, 1989; Nicolosi et al*.,* 1991; Kahlon et al*.,* 1992; Purushothama et al*.,* 1995).

RICE BRAN OIL

Rice bran contains 15-22% oil by weight (Orthoefer, 1996; Patel and Walker, 2004). Crude rice bran oil contains 90-96% of saponifiable and about 4% unsaponifiable lipids. The saponifiable lipids include 68-71% triglycerides, 2-3% diglycerides, 5-6% monoglycerides, 2-3% free fatty acids, 2-3% waxes, 5-7% glycolipids and 3-4% phospholipids (McCaskill and Zhang, 1999) whereas the principal component of the unsaponifiable fraction is γ-oryzanol (Raghuram and Rukmini, 1995). Rice bran oil has excellent fatty acid profile. It has oleic acid (38.4 %), linoleic acid (34.4%) and linolenic acid (2.2%) as unsaturated fatty acids while palmetic acid (21.5%) and stearic acid (2.9%) as saturated fatty acids (Rukmini and Raghuram, 1991). The saturated, monounsaturated and polyunsaturated fatty acids are in the ratio of approximately 1: 2.2: 1.5 (Shin and Chung, 1998; Krishna, 2002). Three major fatty acids, palmitic, oleic and linoleic make up 90% of the total fatty acids of the rice bran oil (Amarasinghe and Gangodavilage, 2004).

Rice bran oil (RBO) is traditionally consumed in Asian rice producing countries with growing interest in Western markets (Jariwalla, 2001; Kim and Godber, 2001; Nasirullah, 2001; Pszczola, 2001). It is in steady demand as ‘‘healthy oil’’ in Japan where approximately 80 thousand tons is consumed annually (Sugano and Tsuji, 1997). Traditionally, rice bran oil has been used for frying food, due to its oxidative stability and flavor; it is now considered as a good substitute for vegetable oils (Sayre and Saunders, 1985; Goenka, 1987). It is widely used in pharmaceutical, food and allied industries due to its unique properties, high medicinal value and therapeutical applications (Cicero and Gaddi, 2001; Amarasinghe and Gangodavilage, 2004). RBO is an unconventional vegetable oil believed to be healthy in some populations (Sugano et al*.,* 1999) due to higher levels of antioxidants (Patel and Walker, 2004) and phytosterols (Stoggl et al*.,* 2005). It is superior to other vegetable oils because it contains ω-3 and ω-6 fatty acids; particularly due to oryzanol and higher amounts of unsaponifiables (Krishna et al*.,* 2005). Currently, efforts are being made to develop RBO with retained non-saponifiable components, while minimizing levels of problematic free fatty acids (Ginsberg et al*.,* 1998).

RICE BRAN PROTEIN ISOLATES

Protein isolates can be prepared from a number of cereal by-products including rice, maize, barley, wheat and rye (Lasztity *et al.,* 1995). Functional properties of the protein play significant role in textural attributes of the final product (Neto et al., 2001). Optimum results can be obtained when both the protein and food’s functional properties are well synchronized. Use of quality protein isolates furnishes food with rich amino acid profile. Plant proteins, being less expensive than animal source, are used to supplement foods with desirable functional attributes (Wiseman and Price, 1987). Textural and functional properties of protein isolates may vary with the processing conditions used for extraction and product manufacturing (Gnanasambandam and Hetiarachchy, 1995; Wagner et al., 1996), nonetheless, thorough study of protein functionality is necessary for food applications.

Functional properties of rice bran protein concentrates are suitable for food application (Jiamyangyuen et al., 2005a). Rice bran protein isolates have promising emulsification properties to be used as natural emulsifier in food products (Lee et al., 2004). Emulsion properties and solubility of bran protein hydrolysates make them suitable for application in array of food products like coffee whiteners, toppings, beverages, confectionary, meat and bakery products (Hamada, 2000). Protein extracts from rice bran has been incorporated in liquid foods like milk and other drinks (Watchararuji et al., 2008). Protein content of baked products was increased by incorporating rice bran protein concentrates without compromising their final quality (Jiamyangyuen *et al.,* 2005b). Balanced amino acid profile and hypoallergenic nature of bran protein are suggestive for its application in infant foods (Wang et al., 1999). Rice protein concentrates in combination with polysaccharide pullulan are converted into edible films with good tensile strength (Shih, 1996). Addition of propylene glycol alginate (PGA) and oil provide resistance against water vapor creating water barrier properties in the films. Cross linking of amino acid and PGA improve films strength through covalent bonding under high pH conditions (Shih, 1994).

HYPOCHOLESTEROLEMIC EFFECTS OF RICE BRAN

Scientific studies support recommendations to increase dietary fiber as part of hyperlipidemia treatment. The hypocholesterolemic effects of rice bran have been demonstrated in experimental animals (Sharma and Rukmini 1987; Seetharamaiah and Chandrashekhara 1989; Kahlon et al*.,* 1992) and humans (Hundemer et al*.,* 1991; Sanders and Reddy, 1992; Hakala et al*.,* 2002). The cholesterol lowering effects of rice bran (fullfat), soybean fiber, oat and barley bran were compared in mice adding 0.06% cholesterol in their diets. Both rice bran and soybean fiber diets had significantly lower total blood cholesterol compared with placebo. Rice bran was found to be the most effective supplement in reducing liver and plasma total cholesterol compared to the control diet. Moreover, mice consuming rice bran diet, demonstrated higher HDL to total cholesterol ratios (Hundemer et al*.,* 1991). In another study, rats fed on diets containing rice and wheat bran showed significant reduction in liver cholesterol and triglycerides. The rice bran diet also increased LDL receptor activity in the liver more than that of wheat bran, hence, effectively lowering plasma cholesterol levels (Topping et al., 1990).

The cholesterol lowering effects of fullfat and defatted stabilized rice bran, parboiled rice bran and rice bran in combination with wheat bran were studied in hamsters fed on fiber diets with 0.5% added cholesterol. The liver cholesterol concentrations, in particular, were significantly lower in animals consuming fullfat stabilized rice bran than all other groups (Kahlon et al*.*, 1990). Rice bran with extremely low β-glucan content is known to be as effective as high–β-glucan oat and barley brans in lowering serum cholesterol (Seetharamaiah and Chandrasekhara, 1989; Kahlon et al*.,* 1990; 1992). The hypocholesterolemic effects of rice bran may be attributed to the unsaponifiable fraction of rice bran oil, primarily phytosterols, tocols (tocopherols and tocotrienols), γ-oryzanol, triterpene alcohol and other minor compounds

(Sharma and Rukmini, 1987; Yoshino et al., 1989; Nicolosi et al., 1991). In a similar study, benefits of bran addition from rice, oats, corn and wheat in diets fed to hamsters were evaluated at relatively high cholesterol level (0.3%). Liver cholesterol concentrations and liver weights were significantly lower for the rice bran diet than for either the corn or wheat bran diets. Animals fed on rice bran had significantly lower VLDL levels and the highest HDL to total cholesterol ratios when compared to all other bran due to greater lipid and sterol excretion (Kahlon et al., 1998).

Chicks were fed on 60% fullfat rice bran and corn/soy diets with 0.5% added cholesterol. Significant differences were found in total cholesterol, triglycerides, high-density and low-density lipoprotein cholesterol. Likewise, in a second study, chicks were fed on fullfat rice bran, defatted rice bran and corn/soy diets balanced for 18% protein, 14.47% total dietary fiber and 10.78% lipid with 0.5% added cholesterol. Total cholesterol and triglycerides were significantly lower in chicks fed on fullfat rice bran diets. Significant differences were found in HDL values for all diets with fullfat rice bran exhibiting the highest (155 mg/dL) and corn/soy exhibiting the lowest mean value (114 mg/dL). Fullfat rice bran appeared to increase HDL and lower LDL in chicks, but did not always affect (TC) total cholesterol (Newman et al., 1992). In an efficacy study, it was found that rice bran might lower cholesterol by increasing short chain fatty acid production in the cecum by hindering cholesterol absorption due to a change in intestinal fluid viscosity or by directly inhibiting cholesterol synthesis in the liver (Fukushima et al., 1999). Rice bran supplementation has been found effective in lowering total cholesterol and LDL levels in human subjects with moderate hypercholesterolemia (Hundemer et al., 1991). However, serum cholesterol was found to be decreased in patients with mild hypercholesterolemia who consumed

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300g/d unpolished rice or 100g/d stabilized rice bran (Hakala et al., 2002). Fullfat rice bran was found to be more effective in lowering cholesterol than isolated rice bran fractions or their combinations (Kahlon et al., 1992).

Rice bran has been found to be equivalent to oat bran in lowering cholesterol. Mildly hypercholesterolemic subjects were fed on treatment diets (100g/day stabilized rice bran or oat bran) with 300mg/day added cholesterol. Total cholesterol levels were significantly reduced in both bran diets when compared to the control (Hegsted et al., 1993). Similarly, changes in plasma lipid levels were studied in men with slightly above the normal cholesterol levels providing test diets containing 35g/day of wheat bran, 60g/day of rice bran or 95g/day of oat bran. The varying amounts of the different brans provided a constant amount of total dietary fiber i.e. 11.8g/day. At baseline level, only oat bran was effective in reducing plasma cholesterol as compared to other treatments. However, the highest rise in HDL was associated with the rice bran diet, resulting in an improved HDL to total cholesterol ratio. Moreover, plasma triglycerides were also lower in case of rice bran compared to wheat bran diet (Kestin et al., 1990).

CHOLESTEROL-LOWERING MECHANISMS

The mechanism of action of rice bran and its oil on lipid metabolism is not yet evident. However, the most probable hypothesis of RBO hypolipidemic action is its specific content of phytosterols, polyphenols (γ-oryzanol) and tocols (tocopherols and tocotrienols). The cholesterol-lowering effects of RBO are possibly attributable to its relatively high unsaponifiables; physiologically bioactive in controlling cholesterol levels in subjects. These compounds have been found to work synergistically to exhibit hypocholesterolemic effects. The brief description of each is given below:

Phytosterols (campesterol, β-sitosterol and stigmasterol)

The phytosterols present in crude rice bran oil like campesterol, β-sitosterol and stigmasterol, have been proven effective in lowering plasma total and LDL-cholesterol without affecting HDL-cholesterol due to similarities in structures of plant sterols and cholesterol (Weststrate and Meijer, 1998).There are several mechanisms through which plant sterols affect cholesterol concentration in the body like formation of non-absorbable complex with cholesterol, altering the size and/or stability of the micelles, interferences with cholesterol esterification in the mucosal cell and interacting with protein receptors required in cholesterol absorption (Rong et al., 1997). It is generally assumed that plant sterols inhibit intestinal absorption of dietary and biliary cholesterol, because of the structural similarities with cholesterol. Some studies indicated that plant sterols contributed more hypocholesterolemic effects than unsaponifiables. In addition, some plant sterols may be more active than others (Wilson et al., 2000). Among the sterols, β-sitosterol has been recognized the predominant cholesterol-lowering component (Vissers et al., 2000; Trautwein et al., 2002).

Polyphenols (oryzanol)

There are numerous mechanisms by which oryzanol lowers cholesterol levels such as: cholesterol-esterase inhibition by cycloartenol or by the inhibition of the accumulation of cholesterol-esters within macrophages or by the modulation of cholesterol acid esterase and acyl-CoA-cholesterol-acyltransferase (Rukmini and Raghuram, 1991); sterol moiety of γ-oryzanol is partly split off from the ferulic acid part in the small intestine by cholesterol esterase (Sugano and Tsuji, 1997); effect on biliary secretion resulting in increased faecal excretion of cholesterol and bile acids (Seetharamaiah et al., 1990); direct inhibition of lipid metabolism (Sakamoto et al., 1987); increased fecal excretion of cholesterol and its metabolites (Wilson et al., 2007) and oryzanol exercises its effects on cholesterol metabolism at sites other than the intestine.

Tocols (tocopherol and tocotrienol)

In case of tocols, cholesterol lowering mechanisms include: antioxidant activity that inhibits cholesterol oxidation (Xu et al., 2001); inhibit HMG-CoA-R, a key enzyme in the endogenous synthesis of cholesterol, via increasing the controlled degradation of reductase protein and decreasing the efficiency of the translation of HMG-CoA-R messenger RNA (Parker et al., 1993; Khor et al., 1995); inhibit the activity of 3-hydroxy-3-methylglutaryl-coenzyme A (HMG-CoA) reductase, the liver enzyme that is critical to the rate at which cholesterol is synthesized (Khor and Ng, 2000); inhibit cholesterol synthesis by suppressing HMG-CoA reductase activity through a posttranscriptional mechanism in HepG2 cells (Pearce et al., 1992; Parker et al., 1993; Qureshi et al., 2000) and via decrease in serum total and LDL cholesterol by inhibiting the hepatic enzymic activity of β-hydroxy-β-methylglutaryl coenzyme A (Qureshi et al., 2002).

SUPPLEMENTATION IN BAKED PRODUCTS

Nowadays, people are becoming more conscious about their health and nutrition. Foods that are convenient with good taste, reasonably priced and carry a favorable nutritional image are in great demand like bakery products especially cakes and cookies. Wheat flour is the primary raw material which provides a matrix in which other ingredients are mixed to form dough or batter. In Pakistan, the predominant use of rice bran is an ingredient in livestock feed. Considering its importance, value-added processing technologies for rice bran have been sought by researchers. The products supplemented with rice bran can play an important role in the existing food crises besides its associated health claims. From a marketing view point, the most abundant available rice bran derived product is the oil (Orthoefer, 1996). Rice bran oil has an impressive nutritional quality, which makes it suitable for nutraceutical products. It has industrial potential particularly in snack food preparation because of great frying stability and with a good fry life and nutty flavor (Sarkar, 1992). Production of margarine from rice bran oil has health benefits with reduced saturated fats and trans-fatty acids.

Rice bran fractions can be used to produce acceptable low fat, high fiber bakery products (Kennedy et al., 1996). *Torticas de Moron*, a traditional Cuban bakery product, was manufactured with 0, 20, 25 or 30% of the usual white flour replaced by parboiled rice bran. Protein, fat, crude fiber and ash were higher in the rice bran *Torticas* than in the control. It was further observed that 25% replacement of flour with rice bran resulted in a product with acceptable sensory properties, chemical composition and shelf life (Zumbado et al., 1997). Rice bran fiber has been reported to contain high amounts of functional proteins and fats along with antioxidants, vitamins and trace minerals in addition to being a concentrated source of fiber. The presence of these nutrients allows rice bran fiber to be used as both nutritional and functional ingredient. Chicken coated with stabilized rice bran fiber tend to absorb less fat during frying while the small amount of fat found naturally in rice bran fiber can act as a carrier for flavors (Hammond, 1994). Later, stabilized rice bran was incorporated @ 5, 10 and 20% in chutney powder. Addition of the rice bran had more affect on color and the least on texture with intermediate effects on aroma, taste and overall acceptability (Prakash and Jyothilakshmi, 1995).

Leavened Pan Bread

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Bread is considered as one of the prime bakery products. Its large loaf volume and fine texture require formation of well developed, elastic dough structure. An essential element in this process is gluten present in the flour (Eneche, 1999). Rice bran is used by the food industry in the production of baked goods, snacks, crackers, breads, and cereals (Rukmani, 2002). The functional properties of fullfat and defatted rice bran were explored by blending rice bran in wheat flour @ 5, 10 and 15% to prepare leavened pan bread. Addition of any of the defatted and fullfat rice brans was associated with reduction in loaf volume and a decrease in overall acceptability of the bread. Breads containing upto 10% of either type of rice bran were still considered acceptable (Sekhon et al., 1997). In another study, stabilized rice bran was successfully incorporated upto 20% for the production of yeast bread. The hygroscopicity of the rice bran improved moisture retention in the baked products while foaming ability improved air incorporation and leavening (Carroll, 1990). In a similar study, bread volume decreased with blending of different types of rice bran; however, the decrease was more pronounced with the defatted bran. Stabilized fullfat rice bran upto 20% level and un-stabilized fullfat or stabilized defatted rice bran upto 10% was found suitable in various food products (Singh et al., 1995).

In commercial production of leavened pan bread, wheat flour was supplemented with rice bran from 15 to 30% and it was observed that it can be supplemented successfully upto 15% replacement level without affecting loaf weight, height or volume (Sharp and Kitchen, 1990). Likewise, leavened pan bread was made by supplementing 10 and 20% processed fullfat and defatted rice bran to study the functional behavior of bread compared with control. Texture profile analysis showed no significant differences as far as cohesive and springiness, but bread hardness, gumminess and chewiness increased with increasing levels of rice bran and were more prominent in bread from defatted rice bran. Measurements of texture exhibited no detrimental effect of adding fullfat rice bran upto 10% and slight hardening of loaves with 20% level compared to control (Lima et al., 2002). Defatted rice bran (DRB) has great potential to be utilized for various bakery products without affecting the nutritional composition and sensory attributes. Overall quality and nutritional profile of pan bread was improved by DRB addition in various proportions. However, fiber and mineral enriched pan bread, with excellent quality, can be prepared by replacing the wheat flour with defatted rice bran upto 5% level without affecting internal and external characteristics of bread (Ajmal et al., 2006). The addition of rice bran to wheat flour increased proteins, lysine and dietary fiber in bread and cookies proportionately to the level of supplementation. In addition to color, flavor, protein extractability, solubility of bran and other properties like water & fat absorption, emulsifying & foaming capacity also showed improvement which further enlightens the potential use of bran in foods (Sharma and Chauhan, 2002). Defatted rice bran increases dough yield, contributes to an attractive tan crust and crumb, does not disturb fermentation or mixing tolerance of dough, causes baked products to remain fresher and more moist (Lynn, 1969). The flour strength and gluten quality decreased at different levels (5, 10, 15, 20 and 25%) of rice bran. The replacement of bran with decreasing amount of gluten has inverse correlation with flour strength. It was concluded that bran supplementation should not exceed to 15%, in flours containing low gluten content (Chumachenko et al., 1987).

Cookies

It is chemically leavened product, also known as “biscuit”. Generally the term biscuit is used in the European countries and cookies in the USA. Biscuits and biscuit like products have been made and eaten by man for centuries (Hoseney, 1986). Cookies are ideal for nutrient availability, palatability, compactness and convenience. They differ from other baked products like bread and cakes because of having low moisture content, ensure comparatively free from microbial spoilage and confer a long shelf life of the product (Wade, 1988). Cookies are considered better for supplemented/composite flours due to their ready-to-eat form, wide consumption, relatively long shelf-life and good eating quality (Tsen et al., 1973). Cookies with high sensoric attributes have been produced from blends of millet/pigeon pea flour (Eneche, 1999), raw rice and wheat (Singh *et al.,* 1989), blackgram and wheat (Singh et al., 1993), chickpea and wheat (Singh et al., 1991), wheat, fonio and cowpea (McWatters et al., 2003) and soybean, chickpea or lupine with wheat (Hegazy and Faheid, 1990). Similarly, cookies with high sensory ratings have been produced from blends of wheat flour and rice bran.

Nutritional and functional properties of rice bran are well suited for baked products like cookies, muffins, breads, crackers, pastries and pancakes (Barber et al., 1981). The fullfat and defatted rice brans were blended in wheat flour @ 5, 10 and 15% to prepare cookies. There was improvement in spread of cookies with the addition of fullfat rice bran. In contrast, there was decrease in the spread of cookies after supplementation of defatted rice bran. Cookies supplemented with either type of rice bran were acceptable upto 10% supplementation level (Sekhon et al., 1997). In another study, cookies were successfully prepared from stabilized rice bran at levels of 20% (Carroll, 1990). In a similar study, stabilized fullfat rice bran upto 20% level and un-stabilized fullfat or stabilized defatted rice bran upto 10% was found suitable in various food products (Singh et al., 1995). Dry heat and extrusion stabilized rice bran was supplemented in wheat flour at 5 to 20% levels for the preparation of cookies (Sharma and Chauhan, 2002). Microwave stabilized defatted rice bran was supplemented in commercial straight grade wheat flout @ 10, 20, 30, 40 and 50% supplementation level to prepare fiber and mineral enriched cookies. It was observed that defatted rice bran can be substituted from 10 to 20% in wheat flour to prepare rice bran supplemented cookies without adversely affecting quality attributes (Sharif et al., 2009).

CONCLUSION

Rice bran, as a co-product of the rice milling industry, is yet not to be efficiently utilized for human consumption. It is composed of pericarp, aleurone and subaleurone layers, parts of the germ and small portion of the starchy endosperm. It is rich in vitamins, minerals, amino acids, dietary fiber, essential fatty acids and plant sterols like γ-oryzanol, tocopherol and tocotrienol having promising health-related benefits. Due to its over all composition, nutritional profile, functional characteristics, and apparent hypoallergenicity, rice bran has many applications in a diet which is characterized by high in dietary fiber and low in saturated fat. It may be particularly beneficial to those individuals who show allergenecity to other cereal grains. Strong evidences are available that the consumption of rice bran may be beneficial in reducing the risk of cardiovascular diseases and colon cancer. There is dire need to consider rice bran as food rather feed ingredient to exploit full potential of this novel functional ingredient.

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