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REVIEW ARTICLE

Germinated brown rice as a value added rice product: A review

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Abstract Rice is a staple food for over half of the world's population. Germinated brown rice (GBR) is considered whole food because only the outermost layer i.e. the hull of the rice kernel is removed which causes least damage to its nutritional value. Brown rice can be soaked in water at 30 °C for specified hours for germination to get GBR. Soaking for 3 h and sprouting for 21 h has been found to be optimum for getting the highest gamma-aminobutyric acid (GABA) content in GBR, which is the main reason behind the popularity of GBR. The intake of GBR instead of white rice ameliorates the hyperglycemia, boosts the immune system, lowers blood pressure, inhibits development of cancer cells and assists the treatment of anxiety disorders. Germination process could be used as enzymatic modification of starch that affects pasting properties of GBR flour. GBR would improve the bread quality when substituted for wheat flour. It is concluded that GBR has potential to become innovative rice by preserving all nutrients in the rice grain for human consumption in order to create the highest value from rice.

Keywords Germinated brown rice · Gamma-aminobutyric acid · Health benefits · Brown rice

Introduction

Rice is a staple food in many parts of the world especially in the East, South and South East Asia, making it the second-most consumed cereal grain. Although rice is a good source of protein, it is not a complete protein. Though in smaller amounts, it contains all of the essential amino acids required for a good health. Bahadur (2003) reported that it is better to eat unpolished (brown) rice, because the outer bran layer of the rice grain, which is removed during the milling process, is rich in fiber, iron, vitamins and minerals. Further, the germination of brown rice (thereby making GBR) is necessary for enhancing nutrients required for a good health. The change of staple food from polished rice to GBR can maintain and promote the healthy life and improve the quality of life (Hiroshi 2005).

GBR is evaluated as a functional food because it is good in digestion and absorption, and contains nutrients such as (GABA) and ferulic acid in plenty as compared to ordinary brown rice. Dried GBR offers an excellent appearance, improved shelf life and handling ease. Unlike white rice, GBR provides more sweetness, excellent taste, has better texture and is easier to cook.

GBR was developed for marketing in Japan in 1995. GBR products were developed and marketed first by Domer Co. (Ueda City, Nagano Pref.) and the city government, Mino-cho of Kagawa Pref., was one of the earliest organizations engaged in the production of GBR. It is now produced by several private companies including agricultural cooperatives. During the last decade, about 49 items related to GBR have been patented. The method for making GBR is quite simple. The brown rice is soaked for one or two nights depending on the ambient temperature and then germinated. This process changes the internal minerals and the brown rice becomes more nutritious, easier to chew and tastier. It has been reported that the GBR may enhance brain functions and reduce level of lipids, or fats, in the blood.

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What is GBR?

GBR is also called as 'sprouted brown rice'. The process of germination enhances the bio-availability of nutrients by neutralizing phytic acid. Consumption of unsprouted grains can lead to poor absorption to nutrients in the grain. The incompletely digested proteins can irritate the intestines, leading to inflammation and allergic reactions. Neutralizing the phytic acid, releasing the proteins, vitamins, and enzymes allow these important nutrients to be absorbed during digestion.

GBR is different from normal brown rice in that it has undergone the process of germination; more specifically, the rice embryo is sprouted under suitable environmental conditions. Generally, brown rice can be germinated by soaking it in warm water of 35–40 °C for about 10–12 h, draining water and keeping in moist condition for 20–24 h, and during soaking period, changing the water every 3–4 h to prevent fermentation (which usually produces undesirable odour) and to maintain consistent water temperature. The result yields a 0.5–1 mm long sprout from the brown rice grain; at this stage nutrient accumulation in the grain is maximum. Manufactured GBR is mostly sold in dried form (the drying does not affect the superior nutritional value accumulated from germination), which looks very similar to ordinary brown rice. The effect of the drying process is to prolong GBR's shelf life.

Background of GBR

Consumption of brown rice became popular in Japan back in the 1970's because of rich fiber and other nutrients contained in the brown rice. However, the popularity did not last long due to the fact that brown rice had to be cooked in the pressure cooker and was still hard to chew and less tasty. GBR overcame the problem which can be cooked in an ordinary rice cooker and is soft enough to chew even for children. GBR has a mellow flavor and a soft mouth feel. Further, GBR is much more nutritious and has numerous health benefits as given in following paragraphs.

Physico-chemical changes

Rasolt (2008) found that acylated steryl gulcoside (ASG) is a growth factor in brown rice after germination which works by increasing levels of good enzymes that help to decrease the diabetes and apparently showed that ASG normalizes dysfunctional enzymes and helps to control blood sugar levels in diabetics. Jiamyangyuen and Ooraikul (2008) reported that effects of germination on cooking and textural properties of cooked rice were more pronounced when rice was soaked and germinated for a longer period. They reported that germinated rice requires less cooking time and water absorbed by kernels during germination resulted in size expansion. From the sensory evaluation, they showed that the cooked germinated rice is sweeter, softer, swelled and cohesive than cooked regular brown rice. Kayahara and Tsukahara (2000) observed that GBR has a softer texture than normal brown rice due to the reaction between phytic acid and minerals during the birth of the sprout which indicates that it can be easily cooked and is easier to digest.

Roohinejad et al. (2009) reported that GABA content after germination in Malaysian brown rice seeds ranged between 0.01 and 0.1 mg/g. The quantity of glutamic acid and protein content varied between 10.1–15.2 mg/g and 6.99–10.17%, respectively. A significant positive correlation exists between the concentration levels of protein and glutamic acid. On the other hand, a significant positive correlation was also observed between the glutamic acid and GABA content.

Nutritional aspects

Various types of analyses on GBR conducted in Japan indicated that during the process of germination, nutrients in the brown rice change drastically. Kayahara et al. (2001) showed that, not only existing nutrients are increased but new components are also released from the inner change due to germination. The nutrients which have increased significantly include GABA, lysine, vitamin E, dietary fiber, niacin, magnesium, vitamin B1, and vitamin B6 (Kayahara et al. 2001; Kayahara 2001). The other nutrients that increased in GBR were inositols, ferulic acid, phytic acid, tocotrienols, potassium, zinc, g-oryzanol, and prolylendopeptidase inhibitor (Kayahara and Tsukahara 2000). In particular, the amount of GABA in GBR was noticed to be ten times more as compared to milled white rice and two times more than that of brown rice. Further, they found that GBR contains less calories and sugar than that in milled rice.

Trachoo et al. (2006) found that germination of rice grains increased many nutrients such as vitamin B, reducing sugar, and total protein contents of GBR were higher than those of brown rice and white rice. Choi et al. (2006) reported that upon 24 h germination, the increased amounts of these nutrients relative to those in the non-GBR were 3.4 times for fructose, 2.75 times for reducing sugars, and 7.97 times for GABA. They observed that the increase in nutrients is higher in case of GBR made by 24 h germination as compared to that made by 48 h germination. Amongst nutrients, a significant increase was observed in GABA contents.

Health effects and benefits of GBR

Nutrition of germinated grains has been studied since decades ago. Kayahara and Tsukahara (2000) concluded that continuous intake of GBR is good for preventing headache, relieving constipation, preventing cancer of colon, regulating blood sugar level and preventing heart disease. Saikusa et al. (1994) found that GABA increases dramatically if brown rice is soaked in 40 °C water for 8–24 h. Okada et al. (2000) reported that intake of GABA suppressed blood pressure and improved sleeplessness, and autonomic disorder observed during the menopausal or presenile period. Mitaka (2000) gave a method to produce GBR, which is easier to absorb and digest than regular brown rice.

GBR helps in preventing Alzheimer's disease, due to its increased GABA content. Go Grains E-News (2004) reported that GBR significantly improved levels of spatial learning in mice. Kayahara and Tsukahara (2000) showed that the brown rice sprouts contain a potent inhibitor of an enzyme called protylendopetidase, which is implicated in Alzheimer's disease (Table 1).

Ito et al. (2005) reported that intake of GBR instead of white rice is effective for the control of postprandial blood glucose concentration without increasing the insulin secretion in subjects with hyperglycemia. Hiroshi (2005) showed that besides containing other useful components, GBR mainly contains two active components viz. GABA, a neurotransmitter which is abounding in brain and spinal cord, and dietary fiber which activates the peristalsis of intestine. It also contains considerable phytic acid with a powerful anticancer activity and a prolyl endopeptidase activity inhibitor related to the metabolism of peptide. Chikako et al. (2005) reported that the protease activity in GBR was increased 1.5 times after germination. They suggested that decrease in soluble proteins and allergens was induced in part by proteolytic degradation and two abundant allergens were degraded in a different manner and probably by different protease in the grains during germination. Varanyanond et al. (2005) investigated that water soaking of rice grains can enrich GABA content which increased as the soaking time was prolonged.

Uses of GBR and its products

In Japan, people in the ancient era may have been eating soaked brown rice (Kayahara and Takamura 2003). Komatsuzaki et al. (2003) reported effects of soaking and gaseous phase sprout processing on the GABA content in GBR. Their study established a processing method that can be used to accumulate high concentrations of GABA.

Ohtsubo et al. (2005) explained that in germinated grains, starch, non-starch polysaccharides and proteins get partially hydrolyzed to sugars, oligosaccharides and amino acids, which also occur in rice. This phenomenon will create bio-functional substances and improvement in palatable texture of cereal grains. In addition, sterilization treatment of GBR—a standard process for commercialized GBR products to reduce micro-organisms—results in an increased amount of glutamic acid, alanine, and glycerin which produce a sweeter and more enhanced flavor as compared to the ordinary brown rice (Ohtsubo et al. 2005).

Watanabe et al. (2004) showed that the substitution of brown rice or GBR for wheat flour lowered specific volume of bread more than the control bread without brown rice (BR) or GBR with increasing amounts of substitution. The improving effect was more obvious for 10 or 20% GBR than for BR. Of the bio-functional components in BR and GBR breads, GABA was unexpectedly decomposed from the final bread. Therefore, GBR would improve the bread quality when substituted for wheat flour. Miyake et al. (2004) concluded that the germination of wheat provided more amounts of amino acid, especially GABA. GBR

Table 1 Selected examples of biological activities in GBR

Nutrients	Biological activities in GBR
GABA	Hypotensive effect, Accelerating metabolism in brain, preventing headaches or depressions aftereffects of cerebral arteriosclerosis and cerebral apoplexy, Preventing climacteric disorder, Preventing presenile derangement such as insomnia and mental irritation, Activating renal function
Dietary fiber	Relieving constipation, Preventing cancer of colon, Regulating blood sugar levels
Inositols	Accelerating fat metabolism, Preventing fatty lever, Preventing arteriosclerosis
Ferulic acid	Scavenging super oxides, Suppressing melanogenesis
Phytic acid	Antioxidative effect, Protecting cardiovascular disease, Preventing platelet aggregation
Tocotrienols	Scavenging super oxides, Protecting skin from ultraviolet rays
Magnesium	Preventing heart diseases
Potassium	Lowering blood pressure
Zinc	Activating reproductive function, Preventing arteriosclerosis
Gamma- oryzanol	Antioxidative effect, Preventing skin aging, Modulating cholesterol values
Prolylendopeptidase inhibitor	Possible preventing Alzheimer's disease

(Kayahara and Tsukahara 2000)

produced after 24 h of incubation showed 2.5 times increase in GABA than before germination. Morita (2004) developed a technology to bake bread with GBR and still have a light loaf. To label bread as having GBR, it must have at least 30% GBR, but that much rice interferes with the gluten and carbon dioxide escapes, causing bread to shrink.

Mamiya et al. (2006) investigated the antidepressant-like effects of GBR and polished rice pellets in comparison with control (AIN-93G) pellets in the forced swimming test and they learned helplessness paradigm in mice. The immobility time on the second day of the forced swimming test was shorter in mice fed with polished rice or GBR pellets than in mice fed with control pellets. These results suggested that the increase of 5-hydroxytryptophan levels in the mouse frontal cortex contributes to the antidepressant-like effects of GBR pellets. GABA, glutamine, and glycerin are amino acids that form certain neurotransmitters of the brain which are inhibitory and have ability to reduce the transmittal of stress, anxiety, grief or depression related messages from the limbic system to the cortex. With a reduction in these messages, the emotional responses will be dampened and make a person feel more relaxed with a better sense of well-being.

Shigeko et al. (2007) showed that the GBR have beneficial effects on psychosomatic health and relationship between lactation, and GBR has attracted interest in terms of mental health and immunity.

Effects of germination on other cereals and pulses

Finney (1978) showed enhancement of nutritional quality of wheat and soybean seeds on germination. Tkachuk (1979) also found similar situation in wheat. Chauhan and Chauhan (2007) observed that 4 days of germination of soybean caused a reduction in anti-nutrients and that the sensory attributes of soy beverages prepared from germinated soybean decreased with increase in the time of germination.

Guleria et al. (2009) studied percent germination, vigour index and lipid composition of germinated seeds located at different node positions of soybean stem axis. Their study revealed significant differences in lipid composition as a function of nodal position of stem axis. The seeds present at the basal nodes showed higher germination percentage, while the vigour index was higher at apical position. Chauhan and Chauhan (2007) studied the effect of germination on anti-nutrients like phytic phosphorus, raffinose, stachyose, trypsin inhibitor activity and saponins in soybean. Germination for 2 days was observed to be optimum for producing soy beverage without any significant change in the sensory attributes and the beverage was devoid of oligosaccharides.

Murugkar and Jha (2009) observed germination ability as well as changes in nutritional and functional qualities on germination of four cultivars of soybean commonly grown in India viz. MAUS-47, DSb1, MACS 450 and JS 9305. They germinated the cultivars at 25 °C with 90% relative humidity for 48 and 72 h and observed that MAUS 47 and JS 9305 showed maximum potential in terms of their germination capacity and length of sprouts, and also maximum decrease in fat, trypsin inhibitor and phytic acid contents. The functional qualities of sprouted soybean varieties were also superior. Varieties MAUS 47 and JS 9305 were found to be most suitable for germination. Chopra et al. (2009) studied the varietal differences and effect of soaking and germination on insoluble (IDF), soluble (SDF) and total dietary fiber (TDF) of Bengal gram, cow pea, dry pea, field bean and green gram. Samples were soaked in water (1:2 ratio) for 12 h at room temperature (29–31 °C), and germinated for different durations and temperatures. Significant varietal differences were observed in the IDF, SDF and TDF content of all legumes. Soaking and germination increased TDF and also led to considerable increase in SDF.

Dave et al. (2008) studied Phytate (IP6) degradation in cowpea, horse gram, moth bean, mung bean, soybean and pearl millet seeds. Soaked, pressure cooked and soaked-cum-germinated seeds were compared with raw seeds. In general, 4–11% of phytate phosphorus decreased during soaking, 17–27% during boiling and 14–22% during germination of seeds. Reduction in IP6 content was 13–19% during soaking, 27–30% during boiling and 32–56% during seed germination. The concentrations of Ca, Mg, Fe and Zn were increased during soaking and germination whereas boiling decreased the Ca, Mg and Fe concentrations. They observed that the solubility of minerals was higher during soaking and germination than during boiling. Sampath et al. (2008) studied the effect of germination on different cereals and pulses considering their importance as prebiotics by estimating oligosaccharides (stachyose, raffinose, maltotriose, maltotetraose, maltopentaose, maltohexaose, maltoheptaose) contents. Germination of seeds for 48 h resulted in complete disappearance of stachyose and raffinose in cereals and pulses. The maltotriose content in pulses completely disappeared on germination but among cereals, 45.1% and 57.3% loss was observed in sorghum and maize, respectively, whereas complete loss was seen in other cereals tested.

Arora et al. (2009) developed two types of food mixtures using raw and germinated barley flour along with whey powder and tomato pulp in 2:1:1 proportion (w/w). The developed food mixtures were mixed with water, autoclaved, cooled and fermented at 37 °C for 12 h with Lactobacillus acidophilus curd containing 106 cells/ml. In germinated and fermented food mixtures, in-vitro digestibility of protein and starch, and in-vitro availability of minerals increased 2 and 4 folds, respectively as compared to non-germinated unprocessed food mixtures.

Gamma-aminobutyric acid and its effects

The reason behind the popularity of GBR among consumers is the significant increase in GABA, a four-carbon non-protein amino acid, which is an inhibitory neurotransmitter that have the following benefits: promotes fat loss by the stimulation of the production of human growth hormone; increases the sleep cycle giving deeper rest; boosts the immune system; lowers blood pressure; inhibits development of cancer cells; assists the treatment of anxiety disorders (Oh and Oh 2004; Ito and Ishikawa 2004). This free amino acid has also effects on accelerating metabolism in brain, preventing autonomic disorders during presenile or menopausal period, and relieving insomnia (Jakobs et al. 1993; Okada et al. 2000; Omori et al. 1987 cited in Komatsuzaki et al. 2003; Kayahara et al. 2001). Further, Ito and Ishikawa (2004) suggested that GABA might have preventive effects on Alzheimer's disease, or help lessen symptoms experienced from this disease and other cerebral-related disorders, such as amnesia and dementia.

Apart from GABA prevalent in GBR, many food scientists are now also focusing on Gamma-oryzanol, ferulic acid, which also increased from the sprouting process. The substance has an anti-oxidative effect that can prevent skin aging and regulate cholesterol levels (Kayahara et al. 2001). However, the increase is not as significant as GABA and its function has not been proved to be as diverse as GABA. Sootthiboon (2007) showed that GABA has a numerous health benefits such as sleep quality enhancement, hypertension and Alzheimer's disease prevention.

Preparation, marketing and products of GBR

The basic procedure for preparing GBR is to select good quality brown rice for germination. The process of germination consists of placing the desired amount of brown rice in a container, covering it with 1–2 cm of water and then soaking it at a temperature of 30–40 °C for 8–20 h. A cooler temperature takes longer time for germination. The water may become slightly smelly and to avoid this, it should be changed every 4–6 h. The part of the seed that germinates is the embryo of rice grain. Oh et al. (2003) showed that the germination of brown rice in a chitosan or glutamic acid solution can significantly increase GABA synthetic activity and the concentration of GABA. Kim et al. (2007) gave a method for preparing GBR.

Market prices of the GBR in Japan are at the range of 1,000 yen (appr. US $ 9) to 800 yen (US $ 7) per kg comparing the prices for the ordinary milled rice ranging from about 300 yen to 600 yen depending upon quality. Although GBR can be easily prepared at home, it is priced extraordinarily high for sale. Now-a-days, GBR products are being sold as much as 15,000 MT in Japan and the marketed value is about 15 billion yen. Total brown rice consumption in Japan is currently about 9 MT. GBR is also served at restaurants. An oriental restaurant in Kyoto is serving home-made GBR since last 5 years. The owner observed that GBR attracts young women. GBR is often quoted in periodicals featuring health and fashion. Both the aged and young mainly for fashion and health appear to appreciate the GBR.

GBR is used to make many products such as rice-balls, soup, bread, doughnuts, cookies, rice burger, etc. GBR is mixed with other materials in these products. GBR has been applied in many dishes in the world. Italian risotto, Spanish paella, Brazilian fejoada, and Indian curry and rice, etc. may be suitable for using with GBR.

GBR and extrusion cooking

The development of a novel foodstuff from GBR by a twin-screw extruder was investigated by Ohtsubo et al. (2005). They prepared GBR by soaking in water for 72 h at 30 °C followed by drying to 13–15% moisture content at 15 °C in a low-humidity artificial weather-control room. Total dietary fiber, total ferulic acid and GABA content of GBR were found to be higher than those of ordinary brown rice or polished rice. They also found that the puffed GBR contained more oryzanol, inositol, total ferulic acid, and total dietary fibers than the unpuffed white rice. Further, they observed that the products prepared by the co-extrusion of GBR (90%) and beer yeast (10%) contained more free amino acids, such as GABA, glycerin, alanine, aspartic acid, and glutamic acid, than white rice, brown rice, and puffed GBR.

Wheat bread prepared with 30% puffed GBR contained more GABA and free sugars, such as maltose, than ordinary wheat bread. The extrudated bread was shown to be sweeter and equivalently palatable as a result of the organoleptic test (Ohtsubo et al. 2005).

Bread from GBR

Morita et al. (2007) used various additives for making GBR breads and evaluated suitable combinations of GBR and additives for bread making to provide GBR bread with high functional properties. The 30% of the wheat flour was substituted with GBR (GBR 30), and they found that combined additions of phytase (PHY), hemicellulase (HEM) and sucrose fatty acid ester (SE) to GBR 30 improved the bread qualities with more suitable dough properties as compared with sample without additives. During fermentation, the amounts of gas leaked from the

GBR 30 dough were suppressed by the additions. PHY and HEM hydrolyzed the phytate and hemicellulose in GBR, and the maturity and extensibility of the GBR 30 dough were caused by the activated yeast with formed phosphate and decomposed bran, making the large loaf volume and softness of breadcrumbs during storage. In addition, SE accelerated the dough tolerance to mixing or fermentation with the emulsifying ability. Consequently, they observed that the combined additions with PHY, HEM, and SE to GBR 30 improved the dough and bread qualities.

Conclusions

From the above review of literature it seems that novel foodstuffs from extruded GBR would be acceptable to consumers and food industry as a promising foodstuff that contains more nutritional and bio-functional components than ordinary rice products. GBR and rice bread are two examples of recent rice products that have been becoming quite popular as GBR holds much more nutrition over milled rice and ordinary brown rice. Despite of the high prices of GBR worldwide, increase in its consumption appears to be prominent. As it can be prepared at home without many efforts, GBR could be well used as a tool to improve food security in food shortage regions, whereas for developed countries, GBR can be a dietary food for health improvement and hence GBR consumption deserves profound popularity throughout the world. The reason behind the popularity of GBR among health-conscious consumers and bio-techno-scientists is the significant increase in GABA and its extensive bio-functional properties to maintain a good human health.

It is concluded that GBR has potential to become innovative rice by preserving all nutrients in the rice grain for human consumption in order to create the highest value from rice. The GBR technology can be transferred for empowerment of rural people, by transforming them into a successful entrepreneurs by starting their own food (GBR) processing units and to contribute in the national development vis-à-vis health and nutritional security and improvement in the living standards. If successful on its generation and dissemination part, this technology will prove to be boon for the rice growers in India.

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