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Mini Review

Rice in health and nutrition

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Abstract

Rice is a dietary staple foods and one of the most importand cereal crops, especially for people in Asia. The consumption of rice is associated with diabetes mellitus due to its high glycemic index. In other hand, some of rice components namely rice bran and rice bran oil contained some minor components which are reported to have some biological effects. Rice can be contaminated by some toxic elements such as arsenic and mercury coming from water and land in which it grows. Besides, some mycotoxins and mould can be present in rice. Therefore, some goverments control rice available in their market. Rice bran will produce rice bran oil and defatted rice bran. Defatted rice bran component consist a number of polysaccharide and dietary fiber that support in cancer and cardiovascular diet therapy. This reviews will cover some new research information on rice, rice bran and rice bran oil, especially in the biological activities and nutritional aspects to human. Such biological activities which are related to rice and its products are decreasing low density lipoprotein level, lowering cholesterol, reducing blood pressure and preventing colorectal cancer.

Introduction

Rice (*Oryza sativa*) is a dietary staple foods and one of the most important cereal crops, especially for people in Asia, but the consumption outside Asia has increased, recently (Orthoefer, 2005). It provides the bulk of daily calories for many companion animals and humans (Ryan, 2011). The glycemic index is one of the popular issues in the world, and people are re-thinking whether consume rice or not. Some study showed that rice consumption is related to the higher risk of diabetes mellitus (McKeown *et al*., 2002; Hu *et al*., 2002). The other studies showed the inverse one. In fact, rice has greater variability of the glycemic index depending on type, cooking method, etc. The unique taste of rice provides easy way to combine rice with the other food to achieve better taste and nutritional balance.

Some studies revealed some health effects of rice and its products (Orthoefer, 2005; Roy *et al.*, 2008; USDA, 2011). The pigment of certain rice can inhibit the formation of atherosclerotic plaque, because it has anti-oxidative or anti-inflammatory effects (Anderson, 2004). Rice is also one of food which is considered to be a potential food vehicle for the fortification of micronutrients because of its regularly consumption. Many studies tried to add iron and zinc to rice in order to reduce the nutritional problems, especially micronutrient deficiencies. A study in Bangladeshi children and their care givers showed that rice was the main source of zinc intake, providing 49% of dietary zinc to children and 69% to women (Arsenault *et al*., 2010).

In the other hand, rice consumption can contribute to arsenic exposure, if the rice consumed contained some toxic elements, like heavy metals and mycotoxins. For example, in US women, there was a positive relationship between rice consumption and urinary arsenic excretion (Gilbert-Diamond *et al*., 2011). However, the arsenic content of rice was still varies in different rice cultivar (Williams *et al.*, 2005). In addition, rice can also be contaminated with pesticides residue coming from land used to grow rice. Most pesticides used in rice are insecticides, and the most common ones were organochlorin and organophosphate such as endosulfan, methylparathion, cypermethrin and monocrotofos (Elfman *et al*., 2011). With the advance of science and technology, rice can be added with whitening agent, which is harmful to human health such as chlorine dioxide (Tsukada and Takeda, 2008). Therefore, these toxic elements present in food should be controlled in order to meet the quality of rice. Some countries have set up the maximum limit of these toxic elements in

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rice.

Nutrients and rice consumption

The nutrients content of rice were varies depending on the variety of rice soil, and the conditions they growth. Rice contributes to the major dietary energy for body. Pre-germinated brown rice has protein two times more than white rice, i.e. 14.6 g/100 g (brown rice) vs 7.3 g/100 g (white rice). In the other hand, the fat content is so high, namely 24.8 g/100 g for pre-germinated brown rice and 1.5 g/100 g for white rice (Seki *et al.*, 2005). The amino acid profile of rice shows that glutamic and aspartic acids are the major amino acids present in rice, while lysine is the limiting amino acid (FAO, 2004). A new method has been developed to achieve high-lysine content of rice, using over-accumulation of lysine-rich BiP (binding protein) in the endosperm (Kawakatsu *et al.*, 2010). Several types of rice (commercial samples of brown, parboiled brown, parboiled milled and milled rice) had similar protein and crude fat contents, however, the ash contents among types of rice were slightly different, mainly among milled samples (Heinemann *et al.*, 2005). The nutrients content of several varieties of rice is shown in Table 1.

Rice is a good source of thiamine (vitamin B1), riboflavin (vitamin B2) and niacin (vitamin B3). Depa *et al.* (2008) reported that the level of vitamin in dehusked rice of three varieties namely Njavara, Jyothi and IR 64 Njavara contained 27 - 32% higher compared to the other two rice varieties. The high thiamine content in Njavara rice could be useful in treating vitamin B1 deficiencies such as muscle weakness and neuritis. One of the strategies for alleviation of micronutrient malnutrition including vitamins in rice is biofortification, for example via Provitamin A biofortification of rice endosperm and engineering higher folate levels in rice endosperm (Bhullar and Gruissem, 2013).

The processing method such as parboiling and milling influences the variability of rice nutrients content. The germ and bran contain high levels of minerals, protein and vitamins. Therefore, removal of the germ and bran from the brown rice produces milled rice which will decrease the nutrients compared to brown rice itself (uncooked) (Roy, 2008). Parboiled milled rice showed 18% ash enrichment in comparison with milled rice, and has higher contents of K and P. Lower contents of Mn, Ca and Zn were observed in parboiled rice, even though the contents of other nutritionally important elements were basically similar to milled rice (Heinemann *et al.*, 2005). As a consequence, rice is fortified with some minerals such as iron (Fe) and zinc (Zn), to prevent diseases

Table 1. The nutrients content of several varieties of 100 g rice (USDA, 2011)

Rice	Water (g)	Energy (kcal)	Protein (g)	Total Lipid (g)	Carbohydrate (g)*	Fiber (g)
Rice, white, glutinous, raw	10.46	370	6.81	0.55	81.68	2.8
Rice, white, glutinous, raw	76.63	97	2.02	0.19	21.09	1.0
Rice flour, white	11.89	366	5.95	1.42	80.13	2.4
Rice flour, brown	11.97	363	7.23	2.78	76.48	4.6
Rice, brown, long-grain, raw	10.37	370	7.94	2.92	77.24	3.5
Rice, brown, long-grain, cooked	73.09	111	2.58	0.90	22.96	1.8
Rice, white, short-grain, raw	13.29	358	6.50	0.52	79.15	2.8
Rice, white, short-grain, cooked	68.53	130	2.36	0.19	28.73	

*Carbohydrate was determined by difference, fiber was total dietary.

associated with mineral deficiencies (Sperottoa *et al.*, 2012).

To retain more thiamine, rice should be not highly milled. However, people usually prefer polished rice (WHO, 1999). The contribution of rice toward the percentage of total dietary energy, protein and fat in some countries was shown in Table 2 (FAO, 2001). Although rice is rich of nutrients, rice alone cannot supply all of the nutrients which are necessary for adequate nutrition. It needs to be complemented with the other food. Animal products and fish are useful addition to the diet, as they provide large amounts of essential amino acids and micronutrients. Pulses, such as beans, groundnuts and lentils, are also nutritional complements to the rice-based diet and help to complete the amino acid profile (FAO, 2004).

As mentioned above, one of the issues in food consumption is glycemic index (GI). Rice has known to have high GI, but International Rice Research Institute (2013) showed that GI of rice varied widely, depending on the type of rice. The variation in GI of rice is due to the differences in the proportion of starch, particularly the ratio of amylose-amylopectin. Only high-amylose varieties are potentially useful in low-GI diets (FAO, 2001). They classified white, brown and parboiled rice as high GI foods. In the other hand, the amylose content is not a good predictor of starch-digestion rate or glycemic response (Panlasigui *et al.*, 1991). High-amylose rice varieties with similar chemical composition including amylase content that were cooked under the same conditions had differences in the starch digestion rate and the glycemic and insulin responses. The differences were not due to unabsorbed carbohydrate, but were related to their physicochemical properties, such as gelatinization temperature, minimum cooking time, amylograph consistency, and volume expansion upon cooking.

The methods of food processing affect the rate of starch then the glycemic index. Modern methods of food processing like extrusion, explosion puffing, and instantization appear to make the starch in these foods more readily digested because of the gelatinization process. *In vitro* study showed that the proportion

Table 2. Contribution of rice (rice-milled equivalent) as percentage of total dietary energy, protein and fat

Country	Supply (g/day)	Dietary energy (%)	Protein (%)	Fat (%)
Bangladesh	441.2	75.6	66.0	17.8
Brazil	108.1	13.5	10.2	0.8
Cambodia	448.6	76.7	69.6	17.3
China	251.0	30.4	19.5	2.5
Ecuador	129.9	16.6	15.5	0.8
India	207.9	30.9	24.1	3.6
Indonesia	413.6	51.4	42.9	8.1
Japan	165.6	23.3	12.5	1.8
Madagascar	251.5	46.6	43.6	11.8
Malaysia	245.2	29.8	20.4	2.2
Nepal	262.3	38.5	29.4	7.2
Peru	127.8	18.8	14.7	1.7
Sri Lanka	255.3	38.4	37.0	2.7
Suriname	189.5	24.7	19.7	1.7
Thailand	285.3	43.0	33.4	4.6
United Arab Emirates	158.4	18.0	10.6	1.1
Viet Nam	464.7	66.7	58.1	14.4

Source: FAO, 2001.

of starch digested was significantly higher for the processed forms of rice, corn, and potato compared with the respective conventionally cooked foods. In human, the plasma glucose response as measured by the GI was significantly higher for five of the six processed forms of rice, corn, and potato compared to the respective traditional versions. Potato crisps were the exception, showing a similar response to that of boiled potatoes (Brand *et al*., 1985).

Rice in diabetes prevention and treatment

Foods with a high glycemic index (GI) have been associated with increased risk of type-2 diabetes, because they are rapidly digested and can cause dramatic increase in blood sugar levels. GI is a widely accepted measure of the effect of carbohydrate foods including rice on human health (Jenkins *et al*., 2002). In other hand, glycemic load (GL) is an extension of the GI concept. The GL value incorporates the amount of rice in a serving in order to better gauge the impact of a diet on postprandial glucose response (Wolever *et al*., 1991). Based on GI, the diets including rice are grouped into three categories, namely low GI (55 or less), medium GI (56 - 69), and high GI (70 or more). Furthermore, based on GL, the diets are classified into low GL (10 or less), medium GL (11 - 19), and high GL (20 or more).

Glycemic index predicts the ranking of the glycemic potential of different meals in individual subjects. Low-GI diets result in modest improvements in overall blood glucose control in patients with insulin-dependent diabetes (type I) and non-insulin-dependent diabetes (type II). The mechanism may through the ability of low-GI diets to reduce insulin secretion and by lowering blood lipid concentrations in patients with hypertriglyceride (Wolever *et al*., 1991). The medium and high glycemic load (GL) rice that most consumed by Bangladeshi was tested for the GI and GL. The high GL rice has a significantly higher GI than medium one (Fatema *et al.*, 2010). Several studies have revealed that high GI diet may have adverse effects on human health such as the risk

Table 3. The glycemic index and glycemic load of some rice (Brand *et al*., 1985)

Rice	Glycemic index (Glucose = 100)	Glycemic load per serving
White rice (Oryza sativa), boiled	69 ± 15	30
White rice, low amylose, boiled	17	7
White rice, high amylose, boiled	39	15
Milled white rice, high amylose, boiled	61	26
Brown rice, boiled	50 ± 19	17
Brown rice, high amylose, boiled	39	16
Parboiled, low amylose rice	51	19
Parboiled, high amylose rice	32 ± 2	12

increase of chronic diseases such as cardiovascular disease (CVD), type II diabetes, and obesity. As a consequence, it is suggested to consume rice with low GI (Jenkins *et al*., 1981). GL is dependent upon the amount of the serving size; so that a smaller serving of this rice and an increased amount of vegetables or other low-carbohydrate dishes can balance the overall glycemic load of the complete diet as well as can provide satiety. Because of this atherogenic role of insulin, it is desirable to control the blood glucose of patients and keep their insulin level as low as possible (Fatema *et al*., 2010).

In Asian population (Chinese and Japanese), the higher consumption of white rice is associated with a significantly increased risk of type II diabetes (Hu *et al*., 2012). The prospective study conducted in Japan showed that elevated intake of white rice is associated with an increased risk of type II diabetes in women. Odds ratio for the highest (762 ± 103 g/dL) compared with the lowest quartiles (226 ± 100 g/dL) of rice intake was 1.65 (Nanri *et al*., 2010). Other study also revealed that intake of white rice was related to the higher risk of diabetes mellitus type II than brown rice (Sun *et al*., 2010). Table 3 shows the GI and glycemic load of several varieties of rice (Atkinson *et al*., 2008).

Based on Table 3, it is known that brown rice has the lower GI index than white rice. Therefore, brown rice is more suitable for patients susceptible for type II diabetes. The γ-aminobutyric acid (GABA) and dietary fiber of pre-germinated brown rice is higher that white rice (Seki *et al*., 2005). GABA is also known to potentiate the insulin secretion in pancreas (Sorenson *et al*., 1991). The administration of water-soluble/oil-soluble fraction-depleted pre-germinated brown rice bran, which is destarched and defatted bran to rat, can decrease the post-prandial blood glucose. This benefit may be derived from dietary fiber (Seki *et al*., 2005).

Rice toxicity and toxic contaminants

Rice may accumulate considerable amounts of essential elements contributing to human health, but some toxic elements can also be present in rice. Some

Table 4. Arsenic concentration in rice in some countries

Country	Type of rice	Arsenic total (μg/g as dry basis weight) Mean (minimal – maximal)	Inorganic Arsenic (μg/g as dry basis weight) Mean (minimal – maximal)	References
Australia	Rice grain	0.03 (0.02–0.04)	-	William *et al.*, 2006
Bangladesh	Rice grain with different varieties	0.08 (0.04 – 0.20)	-	Meharg and Rahman, 2003
	White rice in market basket	0.13 (0.002–0.33)	0.08 (0.01–0.21)	Meharg *et al.*, 2009
	rice grain in households	0.13 (0.002 – 0.557)	-	Rahman *et al.*, 2009
	Rice (Boro season)	0.183 (0.108 – 0.331)	-	Duxbury *et al.*, 2003
	Rice (Aman season)	0.117 (0.072 – 0.170)	-	Duxbury *et al.*, 2003
	Rice grain	0. 136 (0.040 – 0.270)	-	Das *et al.*, 2004
	Rice grain	0.23 (0.04 - 0.65)		Rahman *et al.*, 2010
	Rice in field	0.34 (0.15–0.59)		Ohno *et al.*, 2007
	Rice in the market	0.69 (0.41–0.98)	0.31 (0.23–0.39)	Sun *et al.*, 2008
	Rice in the field	0.13 (0.03–0.30)	0.08 (0.01–0.21)	Williams *et al.*,2005
Canada	Long grain rice	0.11 - 0.34	-	Heitkemper *et al.*, 2001
China	Rice in field	0.501 (0.283 – 0.725)	-	Xie *et al.*, 1998
	Rice in the market	0.14 (0.02–0.46)	0.16 (0.07–0.38)	Meharg *et al.*, 2009
	Rice in the market	0.82 (0.46–1.18)	0.50 (0.25–0.76)	Sun *et al.*, 2008
Egypt	White rice	0.05 (0.01–0.58)	-	Meharg *et al.*, 2009
France	White rice in market	0.28 (0.09–0.56)	-	Meharg *et al.*, 2009
India	White rice in market	0.07 (0.07–0.31)	0.03 (0.02–0.07)	Meharg *et al.*, 2009
	Rice grain	0.16 – 0.58	-	Bhattacharya *et al.*, 2010
	Rice straw	0.004 – 0.015	-	Vicky-Singh *et al.*, 2010
Italy	Rice in the market	0.15 (0.07–0.33)	0.11 (0.07–0.16)	Meharg *et al.*, 2009
Japan	Rice in the market	0.19 (0.07–0.42)		Meharg *et al.*, 2009
Spain	Rice in the market	0.20 (0.05–0.82)		Meharg *et al.*, 2009
	Rice in the market	0.188 ± 0.078	0.114 ± 0.046	Torres-Escribano *et al.*, 2008
Taiwan	Rice in the shed	0.05 (b0.10–0.14)		Lin *et al.*, 2004
	Rice during survey 1993	0.200 (0.190–0.210)		Schoof *et al.*, 1998
	Rice during survey 1995	0.13 (0.063–0.170)		Schoof *et al.*, 1998
Thailand	Rice in the market	0.14 (0.01–0.39)	-	Meharg *et al.*, 2009
USA	Rice in the market	0.25 (0.03–0.66)	0.10 (0.05–0.15)	Meharg *et al.*, 2009
	Rice in surveyed market	0.30 (0.2–0.46)	-	Schoof *et al.*, 1999
Vietnam	Rice in the market	0.21 (0.03–0.47)		Phuong *et al.*, 1999

toxins have been reported in rice or its products. Arsenic is of the heavy metals present in rice, besides mercury (Hg), cadmium (Cd), etc. Besides, some pesticide residues and mycotoxins were also reported in rice.

Heavy metals

Soils can be contaminated by highly toxic heavy metals (such as As, Cu, Cd, Pb and Hg) from either aerial depositions or irrigation. The heavy metals are likely to induce a corresponding contamination in paddy (Nan *et al*., 2002). Paddy in or close to contaminated sites can uptake and accumulate these metals, and then exert potential risk to humans and animals (Fu *et al*., 2008). Malfunction of organs and chronic syndromes may be caused by ingestion of relatively low doses of toxic heavy metals over a long period present in rice. Arsenic is the most toxic heavy metal in rice, therefore, in this chapter; we highlight Arsenic level in rice as a representative of heavy metal.

The chemical form can make the considerable differences in arsenic (As) toxicity. The most toxic form of arsenic compounds is inorganic As (arsenite – As^{3+} and arsenate –As^{5+}), which is also known as class 1 non-threshold carcinogen. This arsenic can be absorbed, distributed, and bounded to plasmatic proteins and accumulated in liver and kidneys (Meharg *et al*., 2009). The metabolites of arsenics namely monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA), are metabolites which are less toxic than parent arsenic. The bioavailability of arsenic species in different forms can help the rice assessment, leading to more accurate estimates of the daily intake of rice. Therefore, the identification of certain forms of arsenic species is the best way to estimate the risk of arsenic (Batista *et al*., 2011).

FAO have recommended that the daily arsenic intake is 15 μg of inorganic As/kg body weight (WHO, 2000), therefore, the toxic effects due to the cumulative arsenic exposure through rice consumption can easily occur in some regions of the world. As a consequence, some scientists have reported the levels of arsenic and other heavy metals in rice or its products. Batista *et al.* (2011) have reported the level of arsenic total and 5 forms of arsenic in 44 different rice samples (white, parboiled white, brown, parboiled brown, parboiled organic and organic white) from different Brazilian regions using liquid chromatography coupled to inductively coupled plasma mass spectrometry. The average level of total arsenic was 222.8 ng/g. The daily intake of inorganic arsenic (the most toxic form) from rice consumption was estimated as 10% of the Provisional Tolerable Daily Intake (PTDI)

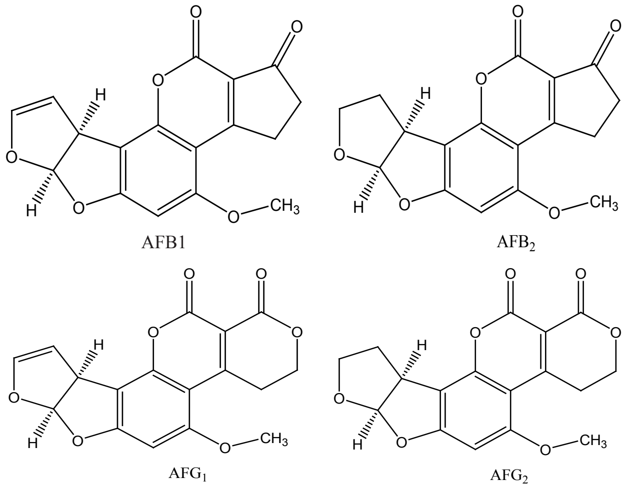

Figure 1. The chemical structure of aflatoxin B_1 (AFB_1), aflatoxin B_2 (AFB_2), aflatoxin G1 (AFG_1), and aflatoxin G_2 ($AFG2_1$)

with a daily ingestion of 88 g of rice, therefore, the average level of arsenic in Brazilian rice was lower than maximum level permissible of As in rice by FAO. Furthermore, inorganic arsenic (As^{3+}, As^{5+}) and dimethylarsinic acid are the main forms of arsenic spesies in all samples.

A study has been carried out to investigate the accumulation and distribution of arsenic in different fractions of rice grain collected in Bangladesh due to the soil contamination with arsenic. The study showed that arsenic content was about 28- and 75-folds higher in root than that of shoot and raw rice grain, respectively. The level of arsenic was higher in non-parboiled rice grain than that of parboiled rice. Two varieties of rice were studied during this study, namely BRRI dhan28 and BRRI hybrid dhan1. The arsenic concentrations in parboiled and non-parboiled brown rice of BRRI dhan28 were of 0.8 ± 0.1 and 0.5 ± 0.0 mg/ kg dry weight, respectively; while those of BRRI hybrid dhan1 were 0.8 ± 0.2 and 0.6 ± 0.2 mg/ kg dry weight, respectively (Azizur *et al*., 2007).

Pasias *et al.* (2013) have investigated the level of different arsenic species in rice and rice flour from different countries (Greece, Thailand and India). The content of total arsenic ranged from 42 μg/ kg to 271 μg/kg for the rice samples and from 22.1 μg/kg to 170 μg/kg for the rice flour samples. The proportion of total inorganic arsenic was equal to (64 ± 19)%, whereas the respective percentage of As^{3+} to total inorganic arsenic was equal to (65 ± 12)%. Furthermore, the level of As^{5+} was determined by the difference of total inorganic As content minus the As^{3+} content. Some of the investigation related to arsenic content in some food was compiled in Table 4. This table can provide the useful information about the range of arsenic concentration in rice worldwide, and to predict the extent of possible dietary intake of

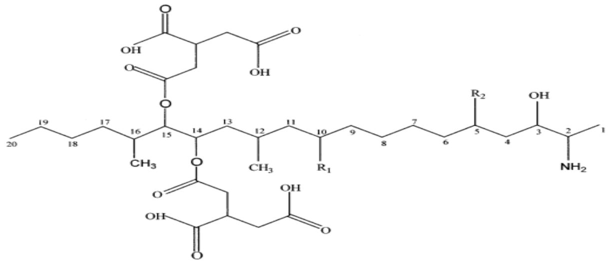

Figure 2. The chemical structure of fumonisin B_1 is 2S-amino-12S,16R-dimethyl-3S,5R,10R,14S,15R-pentahydroxy-eicosane with the C-14 and C-15 hydroxy groups esterified by a terminal carboxyl group of propane-1,2,3-tricarboxylic acid (tricarballylic acid); fumonisin B_2 is 10-deoxy fumonisin B_1; and fumonisin B^3 is 5-deoxy fumonisin B1

arsenic from rice (Azizur *et al*., 2011).

Mycotoxin

Mycotoxin contamination in agriculture products including rice is a serious problem for human health in the tropics and sub-tropics regions, where climatic conditions, agricultural and storage practices are conducive to fungal growth and toxin production (Park *et al.*, 2005; Kumar *et al*., 2008). During the storage, some mycotoxins like aflatoxins, ochratoxin, fumonisin, trichothecenes (deoxynivalenol, nivalenol), and zearalenone can contaminate rice or its products (Gilbert, 2002). The food-borne mycotoxins likely to be of greatest significance for human health in tropical developing countries are the aflatoxins and fumonisins (Kumar *et al*., 2008).

Among the agricultural commodities evaluated, namely rice, wheat, corn, soybeans, and sorghum, rice was the best substrate for the production of aflatoxins (Shotwell *et al*., 1966). Aflatoxins (AFs) are a group of toxic, mutagenic, and carcinogenic secondary metabolites produced primarily by species of *Aspergillus flavus* and *A. parasiticus* (Xiulan *et al*., 2006). AFs have implicated as causative agents in the carcinogenesis of human hepatic and extrahepatic. From epidemiological studies, it is enough evidence that AFs are potent carcinogens, in connection with the incidence of liver cancer in populations exposed to AFs from contaminated foods (Rustom, 1997). Maximum amount of aflatoxins allowed in foodstuffs in some countries (unit, $mgkg^{-1}$) for human consumption and for trading as follow: (Australia, 1 μg/kg; China, 20 μg/kg; EU, 2 μg/kg; India 30 μg/ kg; Japan 10 μg/kg; and Malaysia 35 μg/kg) (Liu *et al.*, 2005).

The most important member of AFs are aflatoxins B_1, B_2, G_1 and G_2 (Saleemullah *et al*., 2006), as shown in Figure 1. The International Agency for Research on Cancer (IARC) has taken into account AFs as probable human carcinogen. As a consequence, some rigorous programs have been developed by various government agencies in regulating aflatoxin levels in foods including rice to hinder human exposure to AFs (CAST, 2003). In food products, fumonisin B_1 and aflatoxin B_1 are considered to be most toxic members (Samapundoa *et al*., 2007). Fumonisin B_1 is currently classified by IARC as a Group 2B (potentially carcinogenic substance), whereas aflatoxin B_1 is classified as a Group 1 (carcinogenic) substance.

Some researchers have reported the presence of aflatoxin in rice in respective regions and countries. Recently, Almeida *et al*. (2012) have investigated several mycotoxins namely aflatoxin B_1, B_2, G_1, and G_2, ochratoxin A (OTA), zearalenone (ZON), deoxynivalenol (DON), and citreoviridin in 230 samples of processed rice and its sub-products or derived products in Brazil. The result showed that 166 rice samples analyzed, 55% had levels <0.11 mg/kg for Aflatoxins. While, 165 rice samples analyzed, 28% and 29% of samples were contaminated with OTA and ZON, with the levels from 0.20 to 0.24 mg/kg (OTA) and from 3.6 - 290.0 mg/kg (ZON), respectively. A survey has been carried out to assess the extent of aflatoxin B_1, B_2, G_1 and G_2 contamination of export-quality rice in Pakistan. A-519 batches of rice (including white, brown and sella rice) from various exporters were analyzed for aflatoxins (Firdous *et al*., 2012). Liu *et al.* (2005) has analyzed aflatoxins in 110 samples in whole grain rice and brown rice covering storage length from 1 yr to over 10 yr in China. The researchers found that the levels of aflatoxins are 3.87 and 0.88 mg/kg, respectively. No significant aflatoxin increase was observed in whole grain rice and brown rice over a 10-year storage period.

Fumonisin B_1 (FB_1) and fumonisin B_2 (FB_2) are the main members of family of mycotoxins produced by various fungan spesies belonging to the *Gibberella fujikuroi* complex (Hinojo *et al*., 2006). IARC classified FB_1 and FB_2 as group 2B or probably carcinogen. The chemical structure of fumonisin B_1 is 2S-amino-12S,16R-dimethyl-3S,5R,10R,14S,15R-pentahydroxy-eicosane with the C-14 and C-15 hydroxy groups esterified by a terminal carboxyl group of propane-1,2,3-tricarboxylic acid (tricarballylic acid); fumonisin B_2 is 10-deoxy fumonisin B_1; and fumonisin B_3 is 5-deoxy fumonisin B_1 (Figure 2). FB_1 is always the most abundant and toxic metabolite of this group of mycotoxins, representing for approximately 70% of the total concentration in naturally contaminated foods and feeds, followed by FB_2 and FB_3 (Murphy *et al*., 1993; Kim *et al.*, 2004).

Although the maximum residue limit (MRL) of FB_1 in rice have not yet been established, to prevent risk of long-term and low-dose exposure of natural contamination, regular monitoring of FB_1 in rice should be carried out. However, the MRL of FB_1 in maize products is set by some regulatory authority bodies. European Union (2006) has stated that MRL of total FB_1 and FB_2 ranged from 0.2 to 2.0 µg/g in maize-based products and unprocessed maize. In addition, The Food and Drug Administration (FDA) has also released guidance related to the levels of total fumonisins in corn and corn-based products at 2.0 - 4.0 µg/g for foods and 5.0 - 100 µg/g for animal feeds (FDA, 2001).

Mallmann *et al.* (2001) have analyzed the level of FB1 in rice available in the market in Brazil. Among samples evaluated, 80% of samples were contaminated with FB1. The highest level of FB_1 found is 14.21 µg/g and the lowest one is 1.14 µg/g, with average level of 4.95 µg/g. Currently, determination of FB_1 contamination of rice samples and its relationship with the rate of esophageal cancer (EC) in a high risk area in northeastern Iran has been carried out by Alizadeh *et al.* (2012) from 22 geographical subdivisions of Golestan province of Iran. Among 66 sampples evaluated, 40.9% of samples were positive to be contaminated with FB_1. The mean of FB_1 levels found is 21.59 µg/g. FB_1 level in rice samples obtained from high risk EC-area was significantly higher (43.8 µg/g) than that in low risk EC-area (8.93 µg/g). The authors concluded that the level of FB_1 in rice samples has the positive correlation with the risk of EC. Tansakul *et al*. (2012) have evaluated the occurrence of FB_1 and FB_2 in red cargo rice from Thailand using sophisticated instrument of high-performance liquid chromatography with electrospray ionization ion trap mass spectrometry (LC-ESI-MS/MS). Among 54 samples from the retail markets, two samples were found to be naturally contaminated with FB1 at a trace level (lower than 5.0 ng/g). None of FB2 was found in any samples.

Besides AFB and FB1, some other mycotoxins which contaminated rice or rice products were also reported by some investigator(s). The presence of ochratoxin A (OTA), zearalenone (ZON), deoxynivalenol (DON), and citreoviridin (CTV) in rice in Brazil has been reported by Almeida *et al.* (2012). DON, nivalenol (NIV), and ZEA levels in rice in Korea were evaluated by Lee *et al.* (2011). A total of 201 samples of brown rice, polished rice, and two types of by-products, blue-tinged rice and discolored rice, were collected from rice stores maintained at 51 rice processing complexes in Korea. Mycotoxins found in discolored rice samples were DON at level of 59 - 1,355 ng/g, NIV in the range of 66 - 4,180 ng/g, and ZEA at 25 - 3,305 ng/g. Polished rice samples were largely free from mycotoxins, although one sample was contaminated with NIV at level of 77.0 ng/g. Makun *et al.* (2011) have analyzed AF, OTA, ZON, DON, FB1, FB2, and patulin (PAT) in 21 rice samples from field (ten), store (six) and market (five) from the traditional rice-growing areas of Niger State, Nigeria. AFs were detected in all samples, at total AF concentrations of 28 - 372 μg/kg. OTA was found in 66.7% of the samples, also at high concentrations (134 - 341 μg/kg) that have to be considered as critical levels in aspects of nephrotoxicity. ZEA (53.4%), DON (23.8), FB1 (14.3%) and FB2 (4.8%) were also found in rice, although at relatively low levels. Riazipour *et al.* (2009) have analyzed T-2 toxin in domestic and imported rice in Iran. A- 140 samples of imported rice (125 samples of Thai and 25 samples of Pakistani rice) and 60 samples of Iranian rice were collected from warehouses of canteens of governmental offices in Tehran. All samples of rice were more or less contaminated with T-2 toxin, but the amount did not exceed the permissible limit.

Mould

When cereal grains (rice) are colonized by moulds, there is a significant risk of contamination with the secondary metabolites of these fungi. A number of these fungal compounds are endowed with toxic effects towards animals and human. Many species of *Fusarium*, *Aspergillus*, *Penicillium* and *Alternaria* are not only recognized as plant pathogens but also are sources of the important mycotoxins of concern in animal and human health (Placinta *et al*., 1999). Mould can contaminate rice during cultivation and handling of rice. If the environment condition fits, the mould can grow and produce mycotoxins. The fungi may later die due to increased temperature or dry periods, but once produced, the stable mycotoxins will remain in the rice (Fredlund *et al.*, 2009).

Pacin *et al.* (2002) have isolated the species of *Fusarium* in newly harvested paddy rice, and low levels of *Fusarium* toxins have been detected in paddy rice. *Aspergillus* spp. are common contaminants of stored rice, besides some species of *Alternaria* and *Penicillium* have also been reported in rice (Park *et al*., 2005; Sales and Yoshizawa, 2005).

Some mould has been reported to be present in rice. Fredlund *et al.* (2009) have detected *Aspergillus*, *Penicillium*, *Eurotium*, *Wallemia*, *Cladosporium*, *Epicoccum*, *Alternaria* and *Trichotecium* in rice. The presence of *Aspergillus flavus* in 21% of the samples (99 rice samples taken from the Swedish retail market) indicated that incorrect management of rice during production and storage implies a risk of mould growth and subsequent production of aflatoxin. The authors stated that high rice consumers may have an intake of 2 - 3 ng aflatoxin/kg bodyweight/day from rice alone. Park *et al.* (2005) reported the presence of *Penicillium verrucosum* as well as ochratoxin A in the most of evaluated rice samples produced in the northern region of Korea.

Rice bran and health and nutrition

Bran, germ, and endosperm play different roles in the human body. In plant, the bran physically protects it from invaders. Bran consists of nutrients and phytochemicals to support the healthy plant. It has similar function in the human body. For humans, bran is also a source of energy and provides some protein, antioxidants, and B vitamins. Although the endosperm provides important nutrients, especially when fortified and enriched, there is a great need for diets to contain more whole grain (Orthoefer, 2005).

Rice bran consisted of 20.9% total dietary fiber in stabilized rice bran and 27.0% in parboiled rice bran. Composition of rice bran for crude protein, fat, fiber and carbohydrate are 12%, 15%, 7% and 31.1%, respectively. Rice bran also contain of 0.3 mg/g calcium, 5 mg/g magnesium, 9 mg/g phytin, 43 μg/g Zinc, 12 μg/g Thiamine, 1.8 μg/g Riboflavin and 267μg/g Niacin. Rice bran is rich in lipids, proteins, minerals, vitamins, phytin, trypsin inhibitor, lipase, and lectin. The high phosphorous content is among the highest of the cereal grains, which is about 11 mg/g. Rice bran is also high in silica (6 mg/g), probably because of the presence of rice hull fragments. Bran is high in B vitamins and tocopherol, but it contains only a little amount of vitamin A and vitamin C (Luh *et al*., 1991). Rice bran fraction will produce two major components, namely rice bran oil and defatted rice bran. A breakdown component from rice bran oil consist a number of fatty acid and flavonoid. Meanwhile, defatted rice bran component consist a number of polysaccharide and dietary fiber that support in cancer and cardiovascular diet therapy (Henderson *et al*., 2012).

Some researches have indicated that whole grain including rice bran is linked to reduced risk of obesity and weight gain. Whole grain intake was inversely related to body mass index (McKeown *et al*., 2002; Newby *et al.*, 2003; Slavin, 2005; Rose, 2005). Those who consumed more whole grain consistently are less of weight gain compared to those who consumed fewer whole grain foods (Liu *et al*., 2003; Koh-Banerjee *et al*., 2004).

Higher consumption of rice bran as a whole grain was linked with a lowered risk of hypertension. Those who eating at least four daily servings of whole grain compare to those eating less than one-half a daily serving were 23% less likely to have hypertension (Wang *et al.*, 2007). Pins *et al.* (2002) found that those who eating a wholegrain as a part of healthy diet will reduce or stop their blood pressure medication compared to those who do not consume the wholegrain. Whole grain is one of the types of food in the Dietary Approaches to Stop Hypertension (DASH) that helped someone to lower blood pressure (Appel *et al*., 1997). Whole grains are related to decreased risk of stroke. This comes as the relationship between stroke and elevated blood pressure. A high cereal fiber diet from the rice bran and whole grain is one of a number of healthy lifestyle factors associated with a decreased risk of ischemic stroke (Kurth *et al*., 2006). Anderson and Pasupuleti (2008) found that whole grain intakes are associated with diabetes and metabolic syndrome. Metabolic syndrome is characterized by abdominal obesity, atherogenic dyslipidemia, elevated blood pressure, and insulin resistance, as well as prothrombotic and proinflammatory states. Metabolic syndrome is related to the development of type 2 diabetes and cardiovascular disease (CVD). Therefore, cereal fiber and whole grain appear to lower the risk of metabolic syndrome and are part of an important public health strategy.

Rice bran and its oil contain large concentrations of several compounds that could potentially prevent chronic diseases such as coronary heart disease and cancer. The epidemiological study showed an inverse association between whole grain ingestion and risk of CVD, including coronary heart disease (CHD), hypertension, and stroke. A meta-analysis study also showed that the regular intake of whole grain was associated with a 26% reduction in the risk of CHD (Anderson, 2004). Human studies show that whole grain decrease risk of cancers of the upper gut (La Vecchia *et al*., 2003) and colorectal cancer risk reduction from 35% to 50% (Wakai *et al*., 2006).

Rice in heart disease and cancer

There are lack studies that have been conducted to conclude the association between certain compounds found in rice bran and health benefit effects. Bioactive food components such as γ-oryzanol, tocopherols, tocotrienols, polyphenols, phytosterols, and carotenoids are found in rice bran. It also contains essential amino acids and micronutrients that work together for health promotion. Selected compounds from rice bran have been investigated for the prevention and control of chronic disease through multiple mechanisms. Rice bran and its oil may have cardiovascular health benefits. Rice bran supplementation in humans has the similar beneficial effects on lipoproteins (Ranhotra *et al.*, 1989; Kestin *et al.*, 1990; Cara *et al*., 1992). The result showed that oat bran was effective in lowering cholesterol's level in human with moderate high blood cholesterol concentrations (Gerhardt and Gallo, 1998). Replacing the usual cooking oils with rice bran oil in hypercholesterol subject showed the decreasing of blood cholesterol's level (Raghuram *et al*., 1989), and it also have the similar effect in middle-aged and elderly subjects (Lichtenstein *et al*., 1994). Rice bran oil contain 20% saturated fatty acids and it is equal amounts of oleic and linoleic fatty acids (Rukmini and Raghuram, 1991). The cholesterol-lowering properties in rice bran can be caused by unsaponifiable component present in rice bran oil (Sugano and Tsuji, 1997; Wilson *et al*., 2000). It includes phytosterols, triterpene alcohols, tocopherols, and tocotrienols, as possible hypocholesterolemic agents.

Evidence suggests that dietary rice bran may exert beneficial effects against breast, lung, liver, and colorectal cancer (Henderson *et al*., 2012). The potential chemopreventive agents in the bran are ferulic acid, tricin, β-sitosterol, γ-oryzanol, tocotrienols/tocopherols, and phytic acid (Barnes *et al.*, 1983). The anticancer effects of the rice bran are mediated through the ability of these agents to induce apoptosis, inhibit cell proliferation, and alter cell cycle progression in malignant cells. These protect against tissue damage through the scavenging of free radicals and the blocking of chronic inflammatory responses. These have also been shown to activate anticancer immune responses as well as affecting the colonic tumor microenvironment in favor of enhanced colorectal cancer chemoprevention. In addition, the low cost of rice production and the accessibility of rice bran make it an appealing candidate for global dietary chemoprevention. Therefore, the establishment of dietary rice bran as a practical food-derived chemopreventive agent has the potential to have a significant impact on cancer prevention for the global population (Fan *et al*., 2000; Kannan *et al.*, 2008).

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