International Food Research Journal 22(3): 1148-1155 (2015)
Journal homepage: http://www.ifrj.upm.edu.my

Composition of amino Acids, fatty acids, minerals and dietary fiber in some of the local and import rice varieties of Malaysia

[1]Thomas, R., [1*]Rajeev Bhat and [2]Kuang, Y.T.

[1]*Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, Penang 11800, Malaysia*
School of Hospitality, Tourism and Culinary Arts, Taylor's University, 47500, Subang Jaya, Selangor, Malaysia

Article history

Received: 18 May 2014
Received in revised form: 12 October 2014
Accepted: 16 October 2014

Keywords

Amino acids content
Mineral content
Heavy metal content
Fatty acid content
Total dietary fiber

Abstract

In this study, three popular, regionally grown rice varieties (Bario, brown and white) were compared with three of the most popular and highly marketed imported rice varieties (black, glutinous and basmati rice) in Penang region of Malaysia. Rice samples were evaluated for amino acids, fatty acids, minerals, heavy metals and dietary fiber composition. Overall, amino acids content among all the rice samples were comparable to each other. Results with regard to minerals showed potassium to be high in brown rice (197.41 mg/100g), while magnesium was recorded to be high in black rice (107.21 mg/100g). Heavy metals such as cadmium, nickel, mercury and lead, though present, they were in negligible amounts. Among all the rice varieties investigated, the total saturated fatty acid and unsaturated fatty acid content was highest in black rice (5.89%). The soluble dietary fiber was higher in white rice (16.39%), whereas insoluble dietary fiber was high in brown (16.51%) and black rice (14.49%), respectively. Results generated from this study is anticipated to benefit both the health wary consumers (based on their potential nutritional attributes) as well as the local food industries to choose the best rice variety while developing novel rice based food products.

Introduction

Of late, with the augmentation in worlds population, the need for potential nutritional sources from plant origin has tremendously increased (Friedman and Brandon, 2001; Bhat and Karim, 2009; Abbas *et al*., 2011). Among the various nutritional attributes, protein quality, minerals and fatty acids content assumes higher significance owing to their potential health benefits. It is well-accepted fact that rice is a popular staple food, consumed by a majority of world's population (Singh *et al*., 2005; Cai *et al*., 2011; Thomas *et al*., 2014 a, b). Rice is a wholesome grain that can fulfill the daily nutritional/ dietary requirements of the local populations. Rice grain encompasses rich amounts of carbohydrate, fiber, protein, fat and minerals. Carbohydrate (nearly 75-85%) in rice grain provides most of the calories associated, whereas protein encompassing eight of the essential amino acids can fulfill other nutritional requirements. Whereas, minerals like iron, copper, zinc, calcium, magnesium, phosphorus and manganese are also found in adequate amounts in rice (Yousaf *et al*., 1992; Parengam *et al*., 2010). In addition, adequate amounts of dietary fiber is also reported to be present in rice grains (Aune *et al*., 2011), thus rendering it a wholesome food.

Owing to the increased demand by consumers for a healthy, natural and a staple food, providing in-depth details on the nutritional qualities of locally grown, indigenous rice varieties assumes high importance. Hence, the present study was planned in order to provide vital foundation informations on the amino acids, minerals, and fatty acids composition of six popular rice varieties (popular as well as highly marketed; 3 locally grown and 3 imported rice varieties) of Penang region in Malaysia. This study is anticipated to benefit both the health wary consumers as well as the local food industries to choose the best rice variety while developing novel rice based food products.

Materials and Methods

Materials

In total, six commonly consumed and popular rice varieties were purchased from a local Supermarket in Penang, Malaysia. The local rice varieties selected included the Brown rice and white rice (medium grain type) (both origin of Kedah region, West Malaysia), and Bario rice varieties (grown in the Bario region of Sabah, East Malaysia). Imported rice varieties, which were used for comparison included: Black rice and glutinous rice (origin of Thailand) and Basmati

*Corresponding author.
Email: *rajeevbhat1304@gmail.com, rajeevbhat@usm.my*
Tel: +60 4653 5212; Fax: +60 4657 3678

rice (origin of Pakistan). Only whole rice grains that maintained 75% of its grain length and without any physical damage were selected for analysis. Rice samples were individually ground to a fine powder (30 mesh size) using a Waring blender (Panasonic MX-898 M, Malaysia), packed in air tight plastic bags and were stored at 4°C for future analysis.

Amino acids analysis

To determine the amino acids content, the method depicted by Zarkadas *et al.* (2007) was adopted. Briefly, individual rice samples (100 mg) was mixed with 6 N HCL (5 ml) and heated (at 110°C for 24 h in an oven). The hydrosylates obtained were mixed with 50 µmol/ml of L-α-amino-n-butyric acid as internal standard (400 µl; AABA). Further, this mixture was made-up with distilled deionized water (100 ml), followed by filtering by using Whatman No 1 filter paper.

Amino acid derivation was undertaken by using 10 µL of sample aliquot and 20 µL AccQ reagent (6-aminoquinolyl-N-hydroxysuccinimidyl carbamate) before being injected into the HPLC column. Analysis was performed using Waters- HPLC System (Milford, MA, U.S.A.) consisting of Waters 1525 binary HPLC pump, 717 plus auto sampler, 2475 multi λ fluorescence detector; wavelength excitation 250 nm, emission 395 nm and a AccQ TagTM amino acid analysis column (3.9 mm x 150 mm; packing material: silica based bonded with C18), which were all based according to the AccQ Tag TM method. The column was maintained at 37 °C and the eluent (flowed at a rate of 1 ml/min.). Chromatographic peaks were plotted and evaluated (using Breeze TM Workstation version 3.20), with two different eluents used (AccQ Tag TM concentrate and Acetonitrile/ Water, 60/ 40%). Amino acids standard mixture was prepared using commercial mixture of standard H (Pierce Chemical, U.S.) which was used as a reference to calibrate the HPLC-system. Besides, methionine and cysteine were determined independently based on the performic acid method.

Minerals content

Mineral analysis was carried out based on the method described by Hooda *et al*. (2006) with slight modifications. Initially, 6 ml of concentrated HNO_3 and 1 ml of 30% (v/v) H_2O_2, which were added to 1 g, sample in a digestion flask. The sample and reagent were left to digest for 15 min using a microwave digester (Milestone Ethos 900 microwave lab station, Sorisole, Italy). The digested samples were then transferred to a 500 ml volumetric flask duplicate. The mineral analysis for potassium, calcium, magnesium, sodium, chromium, iron, manganese and zinc was conducted using atomic absorption spectrophotometer (Perkin Elmer, Waltham, Massachusetts, USA).

Heavy metals

Heavy metals in the rice samples were evaluated based on the standard method of AOAC (2000). In brief, one gram of rice sample was weighed individually in a conical flask followed by addition of nitric acid (10 ml; HNO_3) and the mixture was subjected to digestion. This mixture was heated on a hot plate (temperature of 70°C for 20 min.), followed by addition of 5 ml of perchloric acid ($HCLO_4$). The mixture was allowed to boil until evaporation and once a clear solution of about 3 ml was obtained, this was removed and cooled. For determining the arsenic content, 5 ml of concentrated sulphuric acid (H_2SO_4) was added along with HNO_3 and $HCLO_4$. The digested samples were transferred into a volumetric flask (100 ml) and were made up to the mark using distilled deionized water. After this, the contents were filtered, cooled and used for analysis. Heavy metals such as Selenium, cadmium, copper, nickel, mercury, lead and arsenic were determined using flame atomic absorption spectrophotometer.

Fatty acids profile

Fatty acids profile or the fatty acid methyl esters (FAMES) were determined according to the method described by Firestone (1995) with slight modifications. Approximately, 1 g of rice powdered sample was weighed in a centrifuge tube (50 ml). Before being homogenized at 8000 rpm for 30 Sec using a homogenizer (IKA® T25D, Humboldstratβe, Konigswinter, Germany), 7 ml methanol was added to the extract mixture. This was followed by addition of 14 ml of chloroform and the mixture was again homogenized for another 30 seconds. Samples were analysed using Shimadzu Gas-Chromotography (GC-17A) equipped with an integrator system (GC class VP 4.3) and fitted with a DB 20 column. The conditions inside the GC-FID were formulated according to the method described by Celik and Ercisli (2009). The peaks were identified and compared by relating them to recognized standards.

Total dietary fiber

Total dietary fiber analysis was performed based on the standard gravimetric dietary fiber method (AOAC Official Method 985.29, 2000). This method involves enzymatic treatment for removal of starch and protein. The analysis is separated into 2 parts: Soluble dietary fiber (SDF) and insoluble dietary fiber

(IDF) evaluation. Ethanol was used to precipitate insoluble dietary fiber before being placing in the muffle furnace. A correction for protein and ash in the residue was done. The total dietary fiber, soluble dietary fiber and insoluble dietary fiber were calculated using the following formula:

Dietary fiber (TDF) in the rice samples were calculated by using the following equation:

$$\text{Protein} = \frac{\text{Titration value} \times 0.28 \times 6.25}{\text{Weight of sample (g)} \times 100}$$

$$\% \text{ IDF} = \frac{\text{Average weight of residue (mg)} - \text{Protein} - \text{Ash} - \text{Blank}}{\text{Weight of sample (mg)}} \times 100\%$$

$$\% \text{ SDF} = \frac{\text{Average weight of residue (mg)} - \text{Protein} - \text{Ash} - \text{Blank}}{\text{Weight of sample (mg)}} \times 100\%$$

Statistical analysis

Statistical analysis of the results obtained in this study were subjected to One-way analysis of variance (ANOVA) as well as Tukey's HSD Post-hoc test by using SPSS software (SPSS version 17.0 SPSS Inc., Wacker Drive, Chicago, IL, USA). The level of significance was determined at $P < 0.05$.

Results and Discussion

Amino acids content

The estimated protein quality of a rice grain can be determined by measuring their respective amino acids content (Chen *et al.*, 1986). In the present study, sixteen free amino acids were detected in rice samples, based on the retention time of standard mixture (Table 1). Among these, eight of the major essential amino acids were present in all the rice samples analyzed (except for tryptophan). These included: histidine, thereonine, valine, methionine, lysine, isoleucine, leucine and phenylalanine. Essential amino acids are required in adequate amounts in the normal human diet, as it cannot be produced inside body. The highest amount of essential amino acid found in all rice samples was phenylalanine, which ranged from 33.83-33.86 g/16g N. From the results obtained, there was not much difference in the range observed among the six rice samples analyzed. To support our observations, minor variations in the amino acid content especially that of milled rice have been previously reported (Houston *et al.*, 1969; Hamid *et al.*, 2007).

Besides, the eight essential amino acids, a range of various amino acids were present in the rice samples studied. These included the aspartate (11.83-11.91 g/16 g N), histidine (14.63-14.68 g/16 g N), threonine (18.33-18.47 g/16 g N), valine (28.76-28.77 g/16 g N), methionine (29.28-29.29 g/16 g N). Brown rice had the lowest, whereas, white rice had the highest level of aspartate and serine. Apart from this, aspartic and glutamic acids have been reported to influence the taste of rice, particularly the sweetness and the unique 'umami taste (Kasai *et al.*, 2001). Compared to other cereal varieties, rice normally has high levels of amino acids and protein content (FAO, 1992).

Earlier, Kamara *et al.* (2010) have reported that concentration of amino acids found in rice grains to appreciably influence the sensory qualities in cooked rice, thus affecting the overall acceptability of a rice variety. Overall, among the local rice varieties, Bario rice was found to be better, whereas among the imported rice varieties basmati rice variety was found to be paramount when amino acids was taken into consideration. According to Kerr (2010) basmati rice contains high amount of amino acids, thus rendering them to be one of the most nutritious rice varieties available in the present market.

Fatty acids profile

To facilitate differentiation between fats and oils as well as to analyze the total fat content in a food substrate, fatty acid methyl ester (FAMEs) analysis are performed. The lipid content plays a pivotal role during processing and cooking, and can have high influence on the eating quality of rice (Zhou *et al.*, 2002). Auto-oxidation of lipid can occur when rice is stored for long time duration, thus affecting the overall quality and odour of the cooked rice (Yasumatsu and Moritaka, 1964).

Results obtained for the fatty acids composition of rice in the present study is provided in Table 3. Our results showed palmitic, oleic and linoleic acid to be present in all the rice samples with the highest being in black rice. These results are comparable with the findings of Hwang *et al.* (2002) and Cho *et al.* (2006) who have reported major fatty acids in rice to be: Palmitic, oleic and linoleic acids. Palmitic acid is a saturated fatty acid, whereas oleic acid and linoleic acid are unsaturated fatty acids. In addition to these results, Bario rice showed high amounts of caproic acid at 0.47%.

In this study, the total saturated fatty acid was recorded to be highest in black rice (5.89%) followed by glutinous rice (0.85%). However, for the total unsaturated fatty acids content, black rice had the highest amount (2.03%) followed by brown rice (0.59%). The ratio of unsaturated fatty acid versus saturated fatty acid was recorded to be high in white rice (1.23%) and low in basmati rice (0.20%). Caprylic acid was found only in brown and black

Table 1. Amino acids composition (g/16.0 g N) in different rice varieties evaluated in the study (values are based on 3 independent determinants)

	Local Rice			Imported Rice		
	White	**Brown**	**Bario**	**Black**	**Glutinous**	**Basmati**
Essential amino acids						
Histidine	14.68	14.63	14.66	14.66	14.63	14.63
Threonine	18.47	18.45	18.46	18.45	18.43	18.33
Valine	28.76	28.76	28.79	28.76	28.76	28.77
Methionine	29.28	29.28	29.30	29.28	29.28	29.29
Lysine	31.48	31.47	31.49	31.47	31.47	31.48
Isoleucine	32.42	32.42	32.45	32.32	32.42	32.43
Leucine	32.92	32.91	32.94	32.91	32.91	32.92
phenylalanine	33.84	33.83	33.86	33.84	33.83	33.85
Non-essential amino acids						
Aspartate	11.91	11.83	11.87	11.89	11.85	11.85
Serine	12.97	12.90	12.93	12.94	12.92	12.91
Glutamine	13.49	13.43	13.46	13.46	13.44	13.43
Glycine	14.44	14.39	14.42	14.42	14.39	14.39
Ammonia	15.95	15.89	16.92	15.93	15.89	15.90
Arginine	17.6	17.58	17.58	17.58	17.56	17.57
Alanine	19.86	19.84	19.85	19.83	19.82	19.84
Proline	21.13	23.11	23.12	23.10	23.10	21.12
AABA	25.12	25.11	25.12	25.10	25.10	25.12
Tyrosine	27.70	27.69	27.72	27.69	27.69	27.70

rice varieties. Cis-11-Eicosenoic acid and Erucic acid was present in white and brown rice varieties, respectively. The fatty acid profile of rice grains is noticeably superior when compared to oats, maize, wheat, barley and other cereals. Apart from this, rice grains are reported to have lower levels of saturated fatty acids compared to other staple food or cereals, which renders them to be a healthy and better choice (Cicero and Derosa, 2005; Eshak *et al*., 2011). In addition, as not much research works have been conducted on the levels of dietary fats, the possibility of its use is opined to be destabilized (Oko *et al*., 2012).

Minerals content

Minerals are essential component required in the normal diet as it can promote health to an optimum level. Minerals are naturally found in various foodstuffs, and are at higher levels in those, which are grown directly from the soil (e.g. fruits, vegetables, cereals, grains, etc). Results on the mineral content of various rice samples evaluated in the present study are presented in Table 2. Minerals such as calcium (Ca) and iron (Fe) were high in black rice (21.38 mg/100g) and brown rice (0.81 mg/100g). Macronutrients such as sodium (Na), were low in all samples except for the black rice (10.19 mg/100g). The lower concentration level of sodium in rice can be advantageous for those people who require to restrict the intake owing to high hypertension associated problems (Umadevi *et al*., 2012). Among all the six rice samples analyzed, the dominant macro-mineral detected was potassium (K), which was in the range of 76.12-197.41 mg/100g and magnesium (Mg), which was in the range of 13.49-107.21 mg/100g, respectively. Magnesium and potassium content was found to be high in black (K, 186.54 mg/100g and Mg, 107.21 mg/100g) and brown rice varieties (K, 197.41, mg/100g and Mg, 95/09 mg/100g). Our results are comparable to the observations of Parengam *et al.* (2010). In addition to these, the essential micro-nutrients such as manganese and zinc were found in appreciable amounts in brown rice (1.93 mg/100g) and black rice (0.29) varieties, respectively. Generally, low level of zinc in polished rice is reported compared to unpolished rice (Brinch-Pedersen *et al*., 2007). In this study, zinc level was

Table 2. Minerals and heavy metal content in different rice varieties evaluated in the study (mg/100 g; n =3 ± standard deviation)

	Local Rice			Imported Rice		
	White	Brown	Bario	Black	Glutinous	Basmati
Minerals						
K	84.02	197.41	146.92	186.54	112.58	76.12
Ca	14.85	20.53	12.42	21.38	19.09	16.26
Mg	13.49	95.09	19.64	107.21	17.99	14.89
Na	6.11	6.61	4.99	10.19	6.01	6.39
Cr	<0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
Fe	0.54	0.81	0.46	0.58	0.69	0.54
Mn	0.81	1.93	1.07	0.22	1.05	1.14
Zn	0.16	0.19	0.05	0.29	0.15	0.13
Heavy Metals						
Se	<0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
Cd	<0. 05	<0.05	<0.05	<0.05	<0.05	<0.05
Cu	0.54	0.58	0.46	0.81	0.69	0.54
Ni	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Hg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pb	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
As	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

higher in black rice, and lower in Bario rice. Zinc, being an essential micronutrient is required to be a part of the normal human diet, and its deficiency can lead to a flawed immune system. Above all, it is worthy to mention that nearly one third of the world's population is affected by zinc deficiency (Hotz and Brown, 2004).

With regard to heavy metals, human intervention (such as use of fertilizers in agriculture, mining, etc) can be the route cause for their accumulation (Bhat *et al*., 2010; Sukreeyapongse *et al*., 2010). Since rice is a staple food, growing them in polluted soils can pose serious health risks to humans (Ashifa *et al.*, 2001). In the present study, selenium a proved antioxidant, were present in acceptable threshold levels (< 0.25 mg/100g for all samples). The cadmium content in all the rice samples were below 0.05 mg/100g and did not exceed the limit set by Codex (1995) which is set at 4 mg/100g. The other heavy metals that were detected present in rice samples analyzed as that of mercury and arsenic were below 0.05 mg/100g. The levels of arsenic content did not exceed the permissible limit based on WHO recommendation, which is set at 10 mg/100g (Rahman *et al*., 2007). In recent years, mercury is a common element detected in rice grains (Horvat *et al*., 2003). Presence of low level of mercury can be of help to local populations, as mercury toxicity is known to lead to kidney and gastrointestinal damages (permissible limit set by WHO is 10 mg/100g) (Brandt, 2005). Overall, the rice samples evaluated in this study contained low amount of heavy metals and can still be considered safe for human consumption.

Dietary fiber (Soluble/Insoluble)

Dietary fiber encompasses those fractions of food which are incapable of enzymatically degraded in the digestive tract of human. Rice bran has been reported to encompass high amount of dietary fiber and are routinely being added during preparation of healthy snacks, breakfast cereals, bakery products, etc (Garcia *et al*., 2012, Dakhara *et al*., 2012). Among the dietary fibers, insoluble fiber is reported to be beneficial to overcome constipation problems, whereas soluble fibers can be of help to minimize low-density lipoproteins or cholesterol in the blood. The American Dietetic Association recommends incorporating fresh produce (vegetables and fruits) as well as grains in the daily human diet for health reasons (National Research Council, 1989).

Table 3. Fatty acid profile of different rice varieties evaluated in the study (n = 3; mean ± standard deviation)

Fatty Acid(s)	Chemical Nature	Local Rice			Imported Rice		
		White	Brown	Bario	Black	Glutinous	Basmati
Saturated Fatty Acids (SFA)							
C6:0	Caproic Acid	ND	0.29 ± 0.05	0.47 ± 0.09	3.39 ± 0.26	ND	ND
C8:0	Caprylic Acid	ND	0.02 ± 0.00	ND	0.13 ± 0.09	ND	ND
C10:0	Capric Acid	ND	ND	ND	0.13 ± 0.10	0.19 ± 0.06	0.01 ± 0.00
C12:0	Lauric Acid	ND	ND	ND	0.01 ± 0.00	0.02 ± 0.00	0.02 ± 0.03
C13:0	Tridecanoic acid	ND	ND	ND	0.11 ± 0.08	0.05 ± 0.01	0.04 ± 0.04
C14:0	Myristic Acid	ND	0.01 ± 0.00	ND	0.39 ± 0.3	0.03 ± 0.03	ND
C15:0	Pentadecanoic acid	ND	ND	ND	0.02 ± 0.01	ND	0.01 ± 0.03
C16:0	Palmitic Acid	0.11 ± 0.03	0.27 ± 0.00	0.14 ± 0.02	1.30 ± 0.27	0.51 ± 0.07	0.12 ± 0.01
C17:0	Heptadecanoic acid	0.01 ± 0.00	ND	ND	ND	ND	0.62 ± 0.08
C18:0	Stearic Acid	0.01 ± 0.00	0.02 ± 0.00	ND	0.38 ± 0.29	0.03 ± 0.00	ND
C20:0	Arachidic acid	ND	ND	ND	0.03 ± 0.00	ND	ND
C23:0	Tricosanoic acid	ND	ND	ND	ND	0.02 ± 0.01	ND
Total SFA		0.13	0.61	0.61	5.89	0.85	0.82
Mono- Unsaturated Fatty Acids (MUFA)							
C14:1	Myristoleic Acid	ND	ND	ND	0.03 ± 0.02	0.01 ± 0.01	ND
C15:1	cis-10-Pentadecenoic Acid	ND	ND	ND	0.01 ± 0.01	ND	ND
C18: 1n9	Oleic acid	0.02 ± 0.01	0.21 ± 0.12	0.06 ± 0.009	0.86 ± 0.07	0.16 ±0.02	0.01 ±0.01
C18:1n7	cis-vaccenic acid	0.01 ± 0.01	0.07 ± 0.04	ND	0.01 ± 0.01	ND	ND
C20:1	cis-11-Eicosenoic Acid	0.01 ± 0.006	ND	ND	ND	ND	ND
C22:1n	Erucic Acid	ND	ND	ND	0.02 ± 0.01	ND	ND
Polyunsaturated Fatty acid (PUFA)							
C16:2n4	Hexadecadienoic acid	ND	ND	ND	0.14 ± 0.1	0.06 ± 0.03	0.01 ± 0.01
C16:3n4	hexadecatrienoic acid	ND	ND	ND	0.01 ± 0.00	ND	ND
C18:2n6	Linoleic acid	0.1 ± 0.03	0.32 ± 0.05	0.08± 0.01	0.84 ± 0.76	0.19 ± 0.16	0.13 ± 0.02
C18:4n3	Octadecatetraenoic acid	ND	ND	ND	0.02± 0.01	0.01 ± 0.01	0.01 ± 0.00
C20:3n3	cis-11,14,17-Eicosatrienoic Acid	0.01 ± 0.00	ND	ND	0.02± 0.00	ND	ND
C20:4n6	cis-5,8,11,14-Eicosatetraenoate Acid	0.01 ± 0.01	ND	ND	0.02± 0.03	ND	ND
C20:4n3	Eicosatetraenoic acid	ND	ND	ND	0.01 ± 0.00	ND	0.01 ± 0.02
Total MUFA and PUFA		0.16	0.60	0.14	1.99	0.43	0.17
UFA/SFA		1.23	0.98	0.23	0.34	0.51	0.21

ND-Not Detected

Results on soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) in various rice varieties investigated in this study is shown in Table 4. From the results, IDF was recorded to be higher than SDF in brown, black and basmati rice varieties. However, the white, Bario and glutinous rice had higher amounts of SDF. The highest amount of SDF and IDF was observed in white rice (16.39%) and brown rice (16.51%), respectively. This is in agreement with the American Heart Association (1988) guidelines, wherein it states that brown rice has higher percentage of insoluble dietary fiber compared to other rice samples. White rice on the other hand encompasses high amounts of soluble fiber (Davidson, 2007). According to Wolters (2011), by comparing crude and dietary fiber contents, it is ensured that the rice has low crude fiber content (as it dissolves all soluble fiber and some insoluble fiber). In addition, an excessive amount of dietary fiber is not recommended as it can diminish the absorption of vital vitamins and essential minerals (Saibil, 1989).

Conclusions

Investigations conducted on six different rice varieties (local and imported, marketed in Penang region, Malaysia) did not show much differences in amino acids composition. Rice varieties analyzed had adequate amounts of essential minerals, with low levels of heavy metal contaminants. The fatty acid composition of rice varieties showed a wider range in relation to saturated and unsaturated fatty acid contents. Significant differences existed between the total, soluble and insoluble dietary fibers in the rice varieties studied. Overall, from the results generated, understanding the composition of local rice varieties

Table 4. Dietary fiber content in different rice varieties investigated in this study (n= 3 ± standard deviation)

Sample	Soluble Dietary Fiber (SDF) (%)	Insoluble Dietary Fiber (IDF) (%)
White	16.39 ± 0.07^{c}	4.17 ± 0.05^{a}
Brown	8.35 ± 0.04^{a}	16.51 ± 0.26^{e}
Bario	14.42 ± 0.02^{b}	9.27 ± 0.03^{c}
Black	8.17 ± 0.07^{a}	14.49 ± 0.07^{d}
Glutinous	15.91 ± 0.07^{c}	5.09 ± 0.08^{b}
Basmati	14.48 ± 0.05^{b}	4.14 ± 0.16^{a}

Same letter superscripted in the same column are not significantly different from each other at $P \leq 0.05$

is essential as it is expected to aid in providing details on the nutritional benefits for local populations as well as be of help to local industries while producing novel rice based healthy food products.

Acknowledgements

The first author would like to thank Universiti Sains Malaysia (as Graduate Assistantship) and My Brain program (My masters program) for the funding provided throughout the study. Individual research funds provided as RU grant (No.1001/PTEKIND/814139, USM) for the corresponding author is gratefully acknowledged.

References

Abbas, A., Murtaza, S., Aslam, F., Khawar, A., Rafique, S. and Naheed, S. 2011. Effect of processing on nutritional value of rice *(Oryza sativa)*. World Journal of Medical Sciences 6: 68-73.

American Heart Association. 1988. Dietary guidelines for healthy adults a statement for physicians and health professional by the Nutrition Committee. American Heart Association 77: 721A-724A.

AOAC. 2000. Official methods of analysis. Association of Official Analytical Chemists, 17th Ed., Washington DC, USA.

Ashifa, N., Salim, A., Elias, M. S., Wood, A. K., Sanuri, E., Hamzah, M. S. and Rahman, S. A. 2010. Multielement analysis in rice grain by instrumental neutron activation analysis. Journal of Nuclear and Related Technologies 7: 1-11.

Aune, D., Chan. D. S. M., Lau, R., Vieira, R., Greenwood, D. C., Kampman, E. and Norat, T. 2011. Dietary fiber, whole grains, and risk of colorectal cancer: Systematic review and dose-response meta analysis of prospective cohort studies. British Medical Journal 343: 6617-6620.

Bhat, R. and Karim, A. A. 2009. Exploring the nutritional potential of wild and underutilized legumes. Comprehensive Reviews in Food Science and Safety 8:305-331.

Bhat, R., Kiran, K., Arun, A. B. and Karim, A. A. 2010. Determination of mineral composition and heavy metal content of some nutraceutically valued plant products. Food Analytical Methods 3:181-187.

Brandt, P. 2005. Reports on Food Safety 2005: Food Monitoring. Federal office of consumer protection and food safety. Pp. 16-20.

Brinch-Pedersen, H., Borg, S., Tauris, B. and Holm, P.B. 2007. Molecular genetic approaches to increasing mineral availability and vitamin content of cereals. Journal of Cereal Science 46: 308–326.

Cai, Y., Liu, C., Wang, W. and Cai, K. 2011. Differences in physicochemical properties of kernels of two rice cultivars during grain formation. Journal of Science of Food and Agriculture 91: 1977–1983.

Celik, F. and Ercisli, S. 2009. Lipid and fatty acid composition of wild and cultivated red raspberry fruit (*Rubas idaeus* L.). Journal of Medicinal Plant Research 3: 583- 585.

Chen, H. S., Wu, P. L., Gao, C.C., He, Z. F., Niu, A. Z. and Qing X.H. 1986. Studies on amino acid content of rice protein. Seed 4: 13–19.

Cho, K. S., Kim, H. J., Lee, J. H., Kang, H. H. and Lee, Y. S. 2006. Determination of fatty acid composition in 120 Korean native rice cultivars. Horticulture Science 41: 1082.

Cicero, A. F. G. and Derosa, G. 2005. Rice Bran and its main components: Potential role in the management of coronary risk factors. Nutraceutical Research 3: 29-46.

Codex. 1995. Codex general standard for contaminants and toxins in food and feed, (Codex Standard 193-1995).Codex Alimentarius Commission, Rome, Italy 1995.

Dakhara, S. L., Anajwala, C. C. and Selote, V. S. 2012. Fibrous drugs for curing various common health problems. Pharmacology Review 6: 16-21.

Davidson, J. 2007. IBS Food: Soluble fiber and insoluble fiber foods. *http://www.ibstreatments.com/ibs-foods/* (Assess date 7th October 2014).

Eshak, E. S., Iso, H., Date, C., Yamagishi, K., Kikuchi, S. and Watanabe, Y. 2011. Rice intake is associated with reduced risk of mortality from cardiovascular disease in Japanese men but not women. The Journal of Nutrition 141:595-602.

FAO Corporate Document Repository. 1992. Rice in human nutrition. Agriculture and Consumer Protection.

Firestone, D. 1995. Oils and fats. In: Official Methods of Analysis in AOAC International, 16th Edition (P. Cunnif, ed.). AOAC, Arlington, VA.

Friedman, M. and Brandon, D. L. 2001. Nutritional and health benefits of soy proteins. Journal of Agricultural and Food Chemistry 49: 1069-1086.

Garcia, M.C., Lobato, L.P., Benassi, M.D.T. and Soares, M.S.J. 2012. Application of roasted rice bran in cereal bars. Ciência e Tecnologia de Alimentos, 32:718-724.

Hamid, A. A., Sulaiman, R. R. R., Osman, A. and Saari, N. 2007. Preliminary study of the chemical composition of rice milling fractions. Journal of Food Composition and Analysis 20:627-637.

Hood. W. R., Oftedal, O. T. and Kunz, T. H. 2006. Variation in body composition of female big brown bates *(Eptesicus fuscus)* during lactation. Journal of Comparative Physiology B 176: 807-819.

Horvat, M., Nolde, N., Fajon, V., Jereb, V., Logar, M., Lojen, S., Jacimovic, R., Falnoga, I., Liya, Q., Faganeli, J. and Drobne, D. 2003. Total mercury, methyl mercury and selenium in mercury polluted areas in the province Guizhou, China. Science of the Total Environment 304: 231–256.

Hotz, C. and Brown, K. H. 2004. Assessment of the risk of zinc deficiency in populations and options for its control. Food Nutrition Bulletin 25: 94–204.

Houston, F. R., Allis, H. E. and Kohler G. O. 1969. Amino acid composition of rice and rice by-products. Cereal Chemistry 46: 27-537.

Hwang, Y. H., Jang, Y. S., Kim, M. K. and Lee, H. S. 2002. Fatty acid composition of rice bran oil and growth-promoting effect of rice bran extract and rice bran oil on *Bifidobacterium* and *Lactobacillus*. Agricultural Chemistry Biotechnology 45: 121-124.

Kamara, J. S., Konishi, S., Sasanuma, T. and Abe, T. 2010. Variation in free aminoacid profile among some rice *(Oryza sativa L.)* cultivars. Breeding Science 60: 46–54.

Kasai, M., Ohishi, K., Shimada, A. and Hatae, K. 2001. Taste properties of cooked rice based on an analysis of the cooked rice extracts. Journal of Cookery Science of Japan 34:373-379.

Kerr, G. 2010. Brown basmati rice nutritional information. Online]. [Accessed 10th May 2013]. Available from World Wide Web :*http://www.livestrong.com/article/252914-brown-basmati-rice-nutrition-information/*

National Research Council. 1989. Dietary fiber, in Committee on Diet and Health, Food and Nutrition Board, Commission Life Sciences (Eds.), Diet and health implications for reducing chronic disease risk. Washington, DC, USA: National Academy Press.

Oko, A. O., Ubi, B. E., Efisue, A. A. and Dambaba N. 2012. Comparative analysis of the chemical nutrient composition of selected local and newly introduced rice varieties grown in Ebonyi state of Nigeria. International Journal of Agriculture and Forestry 2: 16-23.

Parengam, M., Kunchit, J., Songsak, S., Sitima, J., Sirinart, L. and Arporn, B. 2010. Study of nutrients and toxic minerals in rice and legumes by instrumental neutron activation analysis and graphite furnace atomic absorption spectrophotometry. Journal of Food Composition and Analysis 23: 340-345.

Rahman, A. M., Hasegawa, H., Rahman, M. M., Rahman, M. M. and Miah, M. A. M. 2007. Accumulation of arsenic in tissues of rice plant (*Oryza sativa* L.) and its distribution in fractions of rice grain. Chemosphere 69: 942-948.

Saibil, F. 1989. Diarrhea due to fiber overload. The New England Journal of Medicine. 320: 599.

Singh, N., Kaur, L., Singh, S.N. and Sekhon, K.S. 2005. Physicochemical, cooking and textural properties of milled rice from different Indian rice cultivars. Food Chemistry 89: 253–259.

Sukreeyapongse, O., Srisawat, L. Chomsiri, O. and Notesiri, N. 2010. The 19th World Congress of Soil Science, Soil Solutions for a Changing World, 1-6th August 2010, Brisbane, Australia. Pp. 51-54.

Thomas, R., Yeoh, T. K., Wan-Nadiah, W. A., Bhat, R. 2014. Quality evaluation of flat rice noodles (kway teow) prepared from Bario and Basmati rice. Sains Malaysiana 43: 339-347.

Thomas, R., Bhat, R., Kuang, Y.T., Abdullah, W.-N.W. 2014. Functional and pasting properties of locally grown and imported exotic rice varieties of Malaysia. Food Science and Technology Research 20: 469-477.

Umadevi, M., Pushpa, R, Sampathkumar, K.P. and Bhowmik, D. 2012. Rice-traditional medicinal plant in India. Journal of Pharmacognosy and Phytochemistry 1: 29-36.

Wolters, A. 2011. Differences of Crude and Dietary Fiber. [Online]. Available from *http://www.livestrong.com/article/480986-differences-of-crude-and-dietary-fiber/#ixzz2ItYtug33* [Accessed date: 10th December 2012].

Yasumatsu, K. and Moritaka, S. 1964. Fatty acid compositions of rice lipid and their changes during storage. Agricultural and Biological Chemistry 28: 257-264.

Yousaf, M. 1992. Study on some physicochemical characteristics affecting cooking and eating qualities of some Pakistani rice varieties. International Journal of Agriculture and Biology 10: 556-560.

Zarkadas. C. G., Gaganon, C., Gleddie, S., Khanizadeh, S., Cober E. R. and Guillemette R. J. D. 2007. Assessment of the protein quality of fourteen soyabean (*Glycine max* (L.) Merr.) cultivars using amino acid analysis and two dimensional electrophoresis. Food Research International 40: 129-146.

Zhou, Z., Robards, K., Helliwell. S. and Blanchard, C. 2002. Review: Composition and functional properties of rice. International Journal of Food Science and Technology 37: 849–868.