International Food Research Journal 18: 705-713 (2011)

Nutritional changes in germinated legumes and rice varieties

[1]Megat Rusydi, M.R., [1]Noraliza, C.W., [1*]Azrina, A. and [2]Zulkhairi, A.

[1]*Department of Nutrition and Dietetics, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*
[2]*Department of Human Anatomy, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*

Abstract: Proximate content and fatty acid composition of germinated and non-germinated legumes (kidney, mung, soy bean and peanut) and rice varieties (red, black, Barrio, brown and milled) were evaluated. In germinated samples, moisture content increased significantly while carbohydrate, protein and fat were decreased significantly. Total dietary fibre was increased in germinated samples except germinated kidney and mung bean. Germination also increased saturated fatty acids (SFA) in legumes, black, red and brown rice. Monounsaturated fatty acids (MUFA) decreased in all samples except germinated kidney, soy and Barrio rice. Polyunsaturated fatty acids (PUFA) increased in some germinated samples (mung bean, peanut, red, brown, Barrio and white rice) but decreased in other legume and rice samples. Generally, palmitic acid increased while stearic, oleic and linoleic acids decreased after germination. Overall, the proximate content and fatty acids of legume and rice varieties changed after germination and may be used as alternate resources for individuals with lifestyle diseases.

Keywords: Germination, legume, rice, proximate content, fatty acid composition

Introduction

Legume is a plant in the family of *Fabaceae* (or *Leguminosae*), or a fruit of these specific plants, characterized by edible seeds, borne in pods that often open along two seams, by pea-shaped flowers, and by compound stipulate leaves (Mazur *et al*., 1998). It is one of the important source of protein, carbohydrate, dietary fibre and minerals (Tharanathan and Mahadevamma, 2003). Soy beans and peanut are well known of their high oil content. Their fat characteristics and fatty acid components have been extensively investigated. On average, soy bean contains 18.0-22.0% oil while peanut contains 40-50% oil (Yoshida *et al*., 2003; Yoshida *et al*., 2004). However, other leguminous seeds were reported to be low in lipid with percentage between 1 and 2% (Akpinar *et al*., 2001).

Rice is a staple food of the world and being a major source of carbohydrates over half the world's population (Ohtsubo *et al*., 2005). Rice is in the grass family of *Gramineae* and related to other grass plants such as wheat, oats and barley which produce grains for food (Padiberas Nasional Berhad, 2009). Rice also provides nutritionally significant amounts of thiamin, riboflavin, niacin and zinc with lesser amounts of other micronutrients (Kennedy *et al*., 2002). There are about 40,000 different varieties of rice worldwide as report by Brown (2008). White rice contains small amount of lipids (below 5% on dry weight basis) predominated with long chain fatty acids such as linoleic (18:2) and linolenic (18:3) acids. In comparison, rice bran is rich in these fatty acids and comprises about 15% on dry weight basis (Wilson *et al*., 2000). Long storage can degrade these unsaturated fatty acids which results in deterioration of flavor, tastiness and eating quality (Zhou *et al*., 2003). In non-glutinous brown rice, lipid content and fatty acids composition are affected by daily mean temperature during the ripening stages (Taira *et al.*, 1979).

Germination is a natural process occurred during growth period of seeds in which they meet the minimum condition for growth and development (Sangronis *et al*., 2006). During this period, reserve materials are degraded, commonly used for respiration and synthesis of new cells prior to developing embryo (Vidal-Valverde, 2002). The process starts with the uptake of water by the quiescent dry seed and terminates with the emergence of the embryonic axis, usually the radical (Bewley and Black, 1994). Several studies on the effect of germination on legumes found that germination can increase protein content and dietary fiber, reduce tannin and phytic acid content and increase mineral bioavailability (Rao and Prabhavathi, 1982; Hussein and Ghanem, 1999; Ghavidel and Prakash, 2007). Germination also was reported to be associated with increase of vitamin concentrations and bioavailability of trace elements and minerals (El-Adawy *et al*., 2004). Kaushik *et*

*Corresponding author.
Email: *azrina@medic.upm.edu.my*

al. (2010) found that germination improves calcium, copper, manganese, zinc, riboflavin, niacin and ascorbic acid content. In cereal grains, germination increase oligosaccharides and amino acids concentration as observed in barley (Rimsten *et al*., 2003), wheat (Yang *et al*., 2001), oat (Mikola *et al*., 2001) and rice (Manna *et al*., 1995). Decomposition of high molecular weight polymers cause generation of bio-functional substances and improvement of organoleptic qualities due to softening of texture and increase of flavor in grains (Beal and Mottram, 1993). In Japan, germination was used to enhance flavor and nutrients in brown rice apart from softened the texture (Ohtsubo *et al*., 2005).

To date, usage and intake of germinated legumes and grains are not common locally. Legumes and cereals (rice varieties) were used as these food groups provide significant amount of macro- and micronutrients to human. Therefore, this study aims to determine the effect of germination process on proximate content and fatty acid composition of dried legumes (kidney, mung, soy bean and peanut) and rice varieties (white, black, red, brown and Barrio rice). Availability of these data is important as the effect of germination on the chemical and biochemical constituents of seeds vary greatly with plant species, seed varieties and the germination conditions such as temperature, light, moisture and the time of germination (Abdus Sattar *et al*., 1989; Bau *et al*., 1997; Kuo *et al*., 2003). Since germination is cheap and more effective in improving nutritional value, it is hoped that this can contribute to nutrition of people.

Materials and Methods

Legumes

Dried legumes (kidney, mung, soy bean and peanut) were purchased from Giant supermarket, Mines Shopping Centre, Seri Kembangan. Legumes were stored in refrigerator at 4°C before germination process.

Rice

Red, black and bario rice were purchased at India Street, Kuching, Sarawak while brown rice and milled white rice were purchased from hypermarket in Serdang, Selangor. Each type of rice was purchased for 1 kg weight. The samples were contained in plastic sealed and stored in refrigerator at 4°C.

Chemicals

Petroleum ether (Merck, Germany), standard of FAMEs (AccuStandard, USA), hexane (Merck, Germany), potassium hydroxide (Merck, Germany), sulfuric acid (BDH Chemicals Ltd, England), sodium hydroxide (Merck, Germany), boric acid (BDH Chemicals Ltd, England), Toshiro indicator, hydrochloric acid (Merck, Germany), perchloric acid (Merck, Germany), glucose stock standard solution (Merck, Germany), Anthrone reagent (BHD, Germany), Celite (HmbG Chemicals, Germany), ethanol (HmbG Chemicals, Germany), butylated hydroxytoluene (Merck, Germany). All the chemicals used were of analytical grade.

Germination process of legumes and rice

Legumes: Samples were washed and cleaned with tap water before soaked for 6 hr in room temperature (28°C). After 6 hr, samples were placed under wet muslin cloth and left germinated for 48 hr in room temperature (28°C) without direct contact with sun light (Yasmin *et al*., 2008).

Rice: Samples were sterilized using 0.1% sodium hypochloric for 30 min and washed with sufficient tap water. Then, samples were soaked in distilled water for 72 hours with the water was changed in every 24 hr (Ohtsubo *et al.*, 2005).

Chemical component analysis

After germination, all legume and rice samples were dried at 60°C using air oven (Memmert, Germany) until constant weight was achieved. Later the dried samples were grind into powder using grinder (Waring, USA) and sieved to comparable particle size.

Moisture, ash, carbohydrate, protein and fat were determined using AOAC (1990) with modifications described by Tee *et al*. (1996). Total dietary fibre was determined using method described by Prosky *et al.*, (1988).

Fatty acid analysis

The fat extracted from legume and rice samples was used to determine their fatty acid compositions.

Preparation of Fatty Acid Methyl Esters (FAME)

About 0.1g of extracted fat from legume and rice samples was transferred into 20 ml screw cap test tube. The oil sample was dissolved in 10 ml of hexane. Then, 0.1 ml of 2N potassium hydroxide (KOH) in methanol was added. Test tube was closed and vortexed for 30 sec. The mixture was centrifuged and the clear supernatant was transferred into 2 ml autosampler vial for fatty acids determination (Frank *et al*., 2006).

Gas chromatography (GC) analysis

Fatty acid composition was analyzed using GC model Agilent 6890 (USA Agilent Technology) equipped with a split-splitness injector, detector Hewlett-Packard EL-980 flame ionization detection (FID) system which was used to separate and quantify each FAME components. DB-23 column with 60m x 0.25 mm I.D., 0.15 µm poththylene glycol film was used to separate the FAMEs. Chemstations software (version 6.0) was used to record and integrated the chromatography data. The oven temperature was held at 50°C for 1 min, before increased to 175°C at 4°C/min and lastly increased to 230°C for 5 min. Temperature for injector and detector was set at 250°C and 280°C, respectively. One micro litre of sample volume was injected with split ratio of 0:50 at column temperature of 110°C. The carrier gas was helium (1.0 ml/min) controlled at 103.4 kPa, hydrogen and air were used for FID and was held at 275.6 kPa (Frank *et al*., 2006).

Statistical analysis

Samples were triplicate for each determination of chemical components and fatty acid composition. The FAME samples were injected two times into the GC and the average value for each of the triplicate samples was used for data analysis. Data was analyzed by using SPSS (Statistical Packages of Social Sciences) software version 16.0. One-way ANOVA and Bonferroni tests were used to analyse the differences in proximate content between germinated and non-germinated samples. Significant differences were determined at $p < 0.05$.

Results and Discussion

Chemical components

As shown in Table 1, moisture content was significantly increased after germination in both legume and rice samples ($p < 0.05$). This finding is similar to the results reported by Khatoon and Prakash (2006) in germinated legumes (green, Bengal and horse gram). However, Ohtsubo *et al*. (2005) found a contradictory finding in the analysis of macronutrients in brown and germinated brown rice that contained lower moisture in the germinated rice samples. As germination proceeds, legumes took up water from the surrounding in order for the metabolic process to commence. Dry legumes absorb water rapidly, influenced by the structure of the legume. The increase in water uptake with time is due to the increasing number of cells within the seed becoming hydrated (Nonogaki *et al*., 2010).

Ash content was significantly decreased in all germinated samples with significant decrease found in germinated mung and soy beans ($p < 0.05$), parallel to observations of Ahmad and Pathak (2000), Ohtsubo *et al*. (2005), Khatoon and Prakash (2006) and Hahm *et al*. (2008). Wang *et al*. (1997) reported that the differences in ash content after soaking for a specific time was due to decreased ash content. The decrease in ash content represents loss in minerals due to rootlet and washing of the rice in water to reduce the sour smell during the period of germination (Tatsadjieu *et al*., 2004).

Carbohydrate content was increased in germinated mung and kidney beans and decreased significantly in germinated white, black, red and brown rice ($p < 0.05$). Vidal-Valverde *et al*. (2002) explained that during germination, carbohydrate was used as source of energy for embryonic growth which could explained the changes of carbohydrate content after germination. Additionally, β-amylase activity that hydrolyzes the starch into simple carbohydrate was increased (Suda *et al*., 1986). Starch in cotyledon was broken down into smaller molecules such as glucose and fructose to provide energy for cell division while the seeds mature and grow (Vidal-Valverde *et al*., 2002; Nonogaki *et al*., 2010). Ohtsubo *et al*., (2005) explained that carbohydrate breakdown in which α-amylase activities were found to parallel with the pattern of starch breakdown.

Protein content was significantly decreased in both germinated legume and rice varieties ($p < 0.05$). Vellupillai *et al*. (2009) observed that the decreased in total protein content is simultaneous with increased in amino acid content caused by increased level of protease activity. Ohtsubo *et al*. (2004) however, found that crude protein content was increased in germinated brown rice. Torres *et al*. (2007) reported there were differences in raw pigeon pea and germinated pigeon pea where the germinated pigeon pea had lesser crude protein content. King and Puwastien (1987) also reported a small decrease in protein nitrogen after 72 hr of germination that could result in decrease of crude protein content of germinated sample. However, other studies done by Khatoon and Prakash (2005), Urbano *et al*. (2005), Ghavidel and Prakash (2007), and Kaushik *et al*. (2010) found different results. They found that total protein increased after germination process. Bau *et al*. (1997) assumed that the increased was due to synthesis of enzyme proteins or a compositional change following the degradation of other constituents. A further explanation was done by Nonogaki *et al*. (2010) where they noted that

Table 1. Chemical components of legume and rice samples

Samples	Moisture(%)	Ash (%)	Carbohydrate(%)	Protein(%)	Fat(%)	Total dietary fiber (%)
Legumes						
Kidney bean						
NG	18.89 ±0.07*	6.27 ± 0.18	27.94 ±3.85	37.78 ± 0.28*	7.58 ± 0.89	54.27 ± 0.60*
G	57.76 ±8.11*	3.34 ± 0.60	21.31 ±2.85	15.40 ± 0.61*	1.76 ± 0.18	32.99 ± 0.51*
Mung bean						
NG	16.53 ± 0.02*	9.36 ± 0.96*	22.32 ±5.41	46.09 ± 0.21*	5.69 ± 0.32	26.79 ± 0.48*
G	62.73 ± 8.60*	4.31 ± 0.05*	15.28 ±6.80	15.79 ± 0.29*	0.89 ± 0.11	24.60 ±0.12*
Soy bean						
NG	8.00 ± 1.21*	3.68 ± 0.09*	37.37 ±2.07*	30.88 ± 0.42*	20.07 ± 0.87*	23.24 ± 0.77*
G	57.05 ±2.45*	1.71 ± 0.17*	17.99 ±3.33*	17.85 ± 0.22*	4.61 ± 1.08*	55.43 ± 1.55*
Peanut						
NG	8.59 ± 0.19*	2.02 ± 0.02	20.06 ±0.8	22.74 ± 0.72*	46.59 ± 6.96*	16.43 ± 0.14*
G	33.31 ± 0.48*	1.20 ± 0.06	16.42 ±7.18	15.09 ± 0.31*	33.98 ± 3.71*	30.83 ±0.21*
Rice varieties						
White						
NG	12.37 ±0.04*	0.41 ± 0.03	77.99 ±7.75*	6.45 ± 0.59*	1.42 ± 0.04*	7.18 ±1.44
G	42.02 ±0.08*	0.27 ± 0.05	52.75 ±3.44*	4.78 ± 0.19*	0.18 ± 0.01*	8.31 ±1.17
Black						
NG	12.57 ± 0.07*	0.62 ± 0.43	76.91 ±0.87*	8.60 ± 0.19*	1.29 ± 0.02*	8.63 ±1.13
G	37.92 ± 0.07*	0.25 ± 0.01	53.21 ±1.84*	6.67 ± 0.26*	0.96 ± 0.02*	9.36 ±0.88
Red						
NG	12.57 ± 0.09*	0.65 ± 0.28	81.69 ±3.40*	6.06 ± 0.26*	1.5 ± 0.09*	7.22 ± 4.20
G	43.09 ± 0.59*	0.20 ± 0.07	48.56 ±4.96*	6.12 ± 0.26*	1.02 ± 0.13*	12.00 ±0.21
Brown						
NG	10.97 ± 0.06*	0.57 ± 0.33	79.21 ±3.43*	6.35 ± 0.82*	1.89 ± 0.04*	8.24 ±1.14
G	39.20 ± 0.43*	0.30 ± 0.02	52.51 ±0.97*	5.49 ± 0.26*	1.49 ± 0.03*	9.61 ±1.75
Barrio						
NG	10.64 ± 0.03*	0.36 ± 0.02	81.34 ±2.13	6.50 ± 0.75*	0.14 ± 0.01	7.28 ±0.54
G	24.14 ± 0.12*	0.07 ± 0.02	71.87 ±0.27	3.83 ± 0.33*	0.07 ± 0.00	8.58 ±1.54

Means marked by (*) are significantly different ($p < 0.05$)
NG: Non-germinated; G: Germinated

protein synthesis occurred during imbibition and that hormonal changes play an important role in achieving the completion of germination. Furthermore, the drop in protein content seems to indicate that proteolysis outpaces protein synthesis in the growing sprouts (Rodriguez *et al*., 2008).

Fat content was decreased in all germinated samples with significant decrease found in germinated soy bean, peanut, white, black, red and brown rice ($p < 0.05$). Similar results occurred in study by Dhaliwal and Aggarwal (1999), El-Adawy *et al.* (2004), Ghavidel and Prakash (2007) and Hahm *et al.* (2008) where the fat content decrease with increase in the time of germination. This is because fat was used as the major source of carbon for seed growth (Bau *et al*., 1997). Hahm *et al.* (2008) also suggested that fatty acids are oxidized to carbon dioxide and water to generate energy for germination.

Total dietary fibres were significantly decreased in germinated kidney and mung beans ($p < 0.05$) but significant increased was found in germinated soy bean and peanut ($p < 0.05$). Martin-Cabrejas *et al.* (2008) reported that the effect of germination on total dietary fibre was dependent on type of legumes. In germinated rice, the amount of total dietary fibre was contributed by the presence of bran layer, an outer layer of rice that contained fibre (Ohtsubo *et al.*, 2005). Study by Azizah and Zainon (1997) demonstrated that total dietary fibre was decreased in soaked wheat, barley, peanut and mung bean, but conversely increased in soaked rice and soy bean. This indicates that germination process affect the level of total dietary fibre during the period of soaking before the actual phase of germination.

Studies have shown that intake of legumes have many health effects in controlling and preventing metabolic diseases such as diabetes mellitus and coronary heart diseases (Slavin *et al*., 1997; Liu *et al.*, 1999). Combination of whole grain and legume powder in coronary artery disease patients without diabetes mellitus can reduce fasting levels of glucose and insulin (Jang *et al*., 2001). Germination meanwhile, altered the biochemical composition of legumes. Decrease of carbohydrate level is beneficial to diabetes mellitus patients. In addition, increase of total dietary fiber and decrease of fat content can give benefit to people with cardiovascular disease and hypercholesterolemia.

There are wide applications of germinated food products besides as ingredient in normal food preparation. Some of the identified uses of germinated legumes and cereals include flour (Pomeranz *et al*., 1977; Giami, 2004; Charoenthaikij *et al*., 2010), beverage (Tonella and Berry, 1987) and weaning food (Marero *et al*., 1988). Bread made using germinated products has increased nutritive value (Charoenthaikij *et al*., 2009) compared to control bread without germination. Tonella and Berry (1987) also found

Table 2. Fatty acid composition of total lipids obtained from legume and rice samples

Fatty acid	Kidney Beans		Mung Beans		Soy Beans		Peanuts		Black		Red		Brown		Barrio		White	
	NG	G	NG	G	NG	G	NG	G	NG	G	NG	G	NG	G	NG	G	NG	G
Caprylic acid (C8:0)	12.18	-	10.22	-	-	-	-	0.71	-	-	-	-	-	-	-	-	0.09	-
Lauric acid (C12:0)	5.11	7.12	4.82	-	-	-	-	-	-	0.12	-	-	-	-	-	0.42	0.06	0.59
Tridecanoic acid (C13:0)	3.04	7.95	3.06	1.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myristic acid (C14:0)	-	-	-	-	-	-	-	-	0.29	0.61	-	0.63	0.44	-	2.91	1.22	0.78	0.59
Palmitic acid (C16:0)	17.92	12.06	18.47	20.76	12.17	12.07	13.54	13.6	13.97	15.16	16.26	32.84	16.81	19.85	97.09	23.73	31.90	19.55
Stearic acid (C18:0)	5.13	2.69	5.32	5.78	4.48	4.17	3.80	3.70	1.77	1.93	2.38	-	2.33	-	-	-	4.87	2.55
Arachidic acid (C20:0)	1.81	1.82	-	3.10	-	0.91	1.73	1.63	-	1.11	-	2.24	-	-	-	1.19	-	0.84
Behenic acid (C22:0)	2.77	12.80	2.89	8.45	-	1.47	-	3.29	-	-	-	-	-	-	-	-	-	-
Lignoceric acid (C24:0)	-	7.36	-	7.10	-	-	1.29	1.21	-	-	-	-	-	-	-	-	-	-
SFA	**47.96**	**51.80**	**44.78**	**46.26**	**16.65**	**18.62**	**20.36**	**23.43**	**16.03**	**18.93**	**18.64**	**35.71**	**19.58**	**19.85**	**100.00**	**26.56**	**37.70**	**24.12**
Pentadecenoic acid (C15:1)	-	10.82	-	-	-	-	-	-	-	-	-	-	-	-	-	0.22	-	-
Oleic acid (C18:1)	9.73	2.52	11.37	3.63	20.40	27.7	37.82	36.78	50.96	48.83	44.65	-	44.65	43.90	-	36.61	49.51	40.14
MUFA	**9.73**	**13.34**	**11.37**	**3.63**	**20.40**	**27.7**	**38.75**	**37.64**	**50.96**	**49.12**	**44.65**	**-**	**44.65**	**44.19**	**-**	**37.46**	**49.82**	**40.40**
Linoleic acid (C18:2)	29.56	18.93	31.16	33.09	54.76	48.53	37.41	36.35	31.87	31.67	35.45	64.10	34.54	35.96	-	33.94	12.06	34.84
Linolenic acid (C18:3, n-3)	12.75	8.88	12.70	17.02	8.19	5.17	-	-	1.16	-	1.27	-	1.24	-	-	-	0.39	1.15
PUFA	**42.31**	**27.81**	**43.86**	**50.10**	**62.95**	**53.7**	**37.41**	**36.35**	**33.03**	**31.67**	**36.72**	**64.10**	**35.78**	**35.96**	**-**	**33.94**	**12.45**	**35.99**
Others	-	7.05	-	-	-	-	5.70	2.73	-	0.56	-	-	-	0.29	-	-	-	-

NG: Non-germinated; G: Germinated

that chocolate beverage made from germinated chickpeas, sugar, cocoa, salt, vegetable oil and water showed reduced viscosity and improved consistency when compared with control formulated using non-germinated chickpeas.

Fatty acid composition

The percentage of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) in germinated and non-germinated legumes and rice samples are as shown in Table 2. Generally, SFA predominate in non-germinated legumes, followed by PUFA and MUFA. Conversely in non-germinated rice varieties, MUFA was the most dominant, followed by PUFA and SFA.

Germination has increased SFA in all legume samples, black, red and brown rice. However, the level of SFA in germinated Barrio and white rice was decreased. Hahm *et al*. (2008) indicated that SFA was decreased in germinated sesame seeds. In our study, palmitic acid (C16:0) was increased in all germinated legumes and rice varieties except in germinated kidney and soy beans and germinated barrio and white rice. Meanwhile, stearic acid (C18:0) was decreased in most germinated legumes and rice varieties except in germinated mung beans and black rice while in germinated red, brown and Barrio rice, stearic acid was not found. This was different with that found by Hahm *et al*. (2008) who indicated an increase of stearic acid and reduced palmitic acid after germination.

In addition, MUFA was increased in germinated kidney, soy bean and Barrio rice, similar to the findings of Hahm *et al*. (2008). Meanwhile in other germinated samples, MUFA was decreased. Oleic acid (C18:1) was the most common MUFA found in all samples. The amount, however, was decreased in most germinated samples except in germinated soy beans and Barrio rice. The result was in contrast with the findings of Hahm *et al*. (2008) as they reported that oleic acid was increased after germination. In germinated kidney beans and Barrio rice, pentadecenoic acid (C15:1) was also found after germination. Comparing the result of germinated legumes with other types of legumes, the oleic acid found was lower than in broad beans (Akpinar *et al*., 2001;Yoshida *et al*., 2008), higher than peas (Yoshida *et al*., 2007) and higher than soy bean (Yoshida *et al*., 2003).

The percentage of PUFA was increased in germinated mung bean, peanut, red, brown, Barrio and white rice whereas, in other legume and rice samples, PUFA was decreased after germination. Similarly, Hahm *et al*. (2008) found that PUFA was decreased in germinated sesame seeds. Linoleic acid (C18:2) was the most common PUFA found in all germinated sample. In germinated legumes, linoleic acid was decreased after germination except in germinated mung beans where the level was increased. This result is similar to Hahm *et al*. (2008) who found in germinated sesame seeds the level of linoleic acid was decreased after germination. Among the germinated rice, linoleic acid was increased after germination except in germinated black rice where slight decreased was found after germination. The amount of linoleic acid found in germinated legumes was lower than that found in broad beans (Yoshida *et al*., 2008), lower than peas (Yoshida *et al.*, 2007) and lower than soy beans (Yoshida *et al*., 2003).

Conclusion

This study reveals that germination in both legume and rice samples increases the moisture content and decrease the ash content in all germinated samples. Carbohydrate content was increased in germinated mung and kidney beans while in other germinated samples, the carbohydrate content was decreased. These changes can be beneficial to diabetes patients as they need to consume less carbohydrate in their diet intake. Protein and fat contents were decreased in all germinated legume and rice samples. Total dietary fibre was decreased in germinated kidney and mung bean while in other germinated samples, total dietary fibre was increased. The changes of fat and total dietary fibre can be beneficial to patients with coronary disease and obesity problems. Germination has increased SFA in all legume samples while in rice samples, SFA content varies (increased in germinated black, red and brown but decreased in germinated Barrio and white rice). MUFA was increased in germinated kidney, soy bean and Barrio rice, while in other germinated samples, MUFA decreased. The percentage of PUFA increased in germinated mung bean, peanut, red, brown, Barrio and white rice whereas, in other legume and rice samples, PUFA was decreased following germination.

Acknowledgements

The authors would like to thank the Department of Nutrition and Dietetics, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia for granting permission to carry out this study and providing the facilities and materials to conduct the

research.

References

Abdus Sattar, Durrani, S.K., Mahmood, F., Ahmad, A. and Khan, I. 1989. Effect of soaking and germination temperatures on selected nutrients and antinutrients of mung bean. Food Chemistry 34 (2): 111-120.

Ahmad, S. and Pathak, D.K. 2000. Nutritional changes in Soy bean during germination. Journal of Food Science and Technology 37 (6):665-666.

Akpinar, N., Akpinar, M.A. and Turkoglu, S. 2001. Total lipid content and fatty acid composition of the seeds of some *Vicia* L. species. Food Chemistry 74 (4): 449–453.

AOAC. 1990. Official Methods of Analysis, 14th ed. Washington DC: Association of Official Agricultural Chemists.

Azizah, A.H. and Zainon, H. 1997. Effect of processing on dietary fiber contents of selected legumes and cereals. Malaysia Journal of Nutrition 3(2):131-136.

Bau, H., Villaume, C., Nicolas, J. and Mejean, L. 1997. Effect of germination on chemical composition, biochemical constituents and antinutritional factors of soya bean (*Glycine max*) seeds. Journal of the Science of Food and Agriculture 73(1): 1-9.

Beal, A.D. and Mottram, D.S. 1993. An evaluation of the aroma characteristics of malted barley by free-choice profiling. Journal of the Science of Food and Agriculture 61(1):17- 22.

Bewley, J.D. and Black, M., 1994. Seeds: Physiology of Development and Germination. In Seeds: Germination, Structure, and Composition, p. 1-2. Plenum Press, New York.

Brown, A. 2008. Understanding Food, Principles and Preparation. In Cereal, Grains and Pasta, p. 321-322. Thomson/Wadsworth Learning, USA.

Charoenthaikij, P., Jangchud, K., Jangchud, Piyachomkwan, K., Tungtrakul, P. and Prinyawiwatkul, W. 2009. Germination Conditions Affect Physicochemical Properties of Germinated Brown Rice Flour. Journal of Food Science 74 (9): 658-665.

Charoenthaikij, P., Jangchud, K., Jangchud, A., Prinyawiwatkul, W., Hong, K.N. and King, J. M. 2010. Physicochemical Properties and Consumer Acceptance of Wheat-Germinated Brown Rice Bread during Storage Time. Journal of Food Science 75 (6): 333-339.

Dhaliwal, Y.S. and Aggarwal, R.A.K. 1999. Composition of fat in soybeans as affected by duration of germination and drying temperature. Journal of Food Science and Technology 36 (3) 266-267.

El-Adawy, T.A., Rahma, E.H., El-Bedawey, A.A. and El-Beltagy, A.E. 2004. Nutritional potential and functional properties of germinated mung bean, pea and lentil seeds. Plant Foods for Human Nutrition 58(3): 1-13.

Frank, D., Pat, S. and Philip, L.W. 2006. Improving the analysis of fatty acids ,ethyl esters using retention time locked methods and retention time databases. Agilent Technologies 1-5.

Ghavidel, R.A. and Prakash, J. 2007 The impact of germination and dehulling on nutrients, antinutrients, in vitro iron and calcium bioavailability and in vitro starch and protein digestibility of some legume seeds. LWT 40 (7): 1292-1299.

Giami, S.Y. 2004. Effect of germination on bread-making properties of wheat-fluted pumpkin (*Telfairia occidentalis*) seed flour blends. Plant Foods for Human Nutrition 58(3): 1-9.

Hahm, T., Park, S. and Lo, Y.M. 2008. Effects of germination on chemical composition and functional properties of sesame (*Sesamum indicum* L.) seeds. Bioresource Technology 100 (4) 1643-1647.

Hussein, L., and Ghanem, K. Z. 1999. Calcium bioavailability from selected Egyptian foods with emphasis on the impact of germination and fermentation. International Journal of Food Sciences and Nutrition 50(5): 351–356.

Jang, Y., Lee, J.H., Kim, O.Y., Park, H.Y. and Lee, S.Y. 2001. Consumption of whole grain and legume powder reduces insulin demand, lipid peroxidation, and plasma homocysteine concentrations in patients with coronary artery disease: randomize controlled clinical trial. Arteriosclerosis, Thrombosis and Vascular Biology 21(2001): 2065-2071.

Kaushik, G., Satya, S. and Naik, S.N. 2010. Effect of domestic processing techniques on the nutritional quality of the soybean. Mediterranean Journal of Nutrition and Metabolism 3(1): 39-46.

Kennedy, G., Burlingame, B. and Nguyen, V.N. (2002). Nutritional Contribution of Rice: Impact of Biotechnology and Biodiversity in Rice-Consuming Countries, the International Rice Commission. Online available at *http://www.fao.org/docrep/006/y4751e/y4751e05.htm* Accessed on Aug 26, 2010.

King, R.D. and Puwastien, P. 1987. Effects of Germination on the Proximate Composition and Nutritional Quality of Winged Bean (*Psophocarpus tetragonolobus*) Seeds. Journal of Food Sciences 52 (1): 106-108.

Khatoon, N. and Prakash, J. 2006. Nutrient retention in microwave cooked germinated legumes. Food Chemistry 97 (1): 115-121.

Kuo, Y., Rozan, P., Lambein, F., Frias, J. and Vidal-Valverde, C. 2003. Effects of different germination conditions on the contents of free protein and non-protein amino acids of commercial legumes. Food Chemistry 86 (4): 537-545.

Liu, S., Stampfer, M.J., Hu, F.B., Giovannucci, E., Rimm, E., Manson, J.E., Hennekens, C.H. and Willett, W.C. 1999. Whole-grain consumption and risk of coronary heart disease: results from the Nurses' Health Study. American Journal of Clinical Nutrition 70(3): 412–419.

Manna, K.M., Naing, K.M. and Pe, H. 1995. Amylase activity of some roots and sprouted cereals and beans. Food and Nutrition Bulletin 16(2): 1- 4.

Marrero, L.M., Payumo, E.M., Librando, E.C., Lainez, W.N., Gopez, M.D. and Homma, S. 1988. Technology of weaning food formulations prepared from germinated cereals and legumes. Journal of Food Science 53(5): 1391-1395.

Martin-Cabrejas, M.A., Diaz, M.F., Aguilera, Y., Benitez, V., Molla, E. and Esteban R.M. 2008. Influence of germination on the soluble carbohydrates and dietary fibre fractions in non-conventional legumes. Food Chemistry 107 (3): 1045-1052.

Mazur, W.M., Duke, J.A., Wahala, K., Rasku, S. and Adlercreutz, H. 1998. Isoflavanoids and lignans in legumes: Nutritional and health aspects in humans. Nutritional Biochemistry 9 (4): 193-200.

Mikola, M., Brinck, O. and Jones, B.L. 2001. Characterization of oat endoproteinases that hydrolyze oat avenins. Cereal Chemistry 77 (5): 55–58.

Nonogaki, H., Bassel, G.W. and Bewley, J.W. 2010. Germination-still a mystery. Plant Science doi:10.1016/j.plantsci.2010.02.010.

Ohtsubo, K., Suzuki, K., Yasui, Y. and Kasumi, T. 2005. Bio-functional components in the processed pre-germinated brown rice by a twin-screw extruder. Journal of Food Composition and Analysis 18 (4): 303–316.

Padiberas Nasional Berhad. 2009. Online availabe at *http://www.bernas.com.my/ process.htm* Accessed on July, 26 2009.

Pomeranz, Y., Shogren, M.D. and Finney, K.F. 1977. Flour from germinated soybeans in high-protein bread. Journal of Food Science, 42(3): 824-827.

Prosky, L., Asp, N.G., Schweizer, T.F., DeVries, J.W. and Eurda, J. 1988. Determination of insoluble, soluble and total dietary fiber in foods and food products: Collaboration study. Journal -Association Official Analytical Chemist 71(5): 1017-1023.

Rao, B. S. N., and Prabhavathi, T. 1982. Tannin content of foods commonly consumed in India and its influence on ionisable iron. Journal of the Science of Food and Agriculture 33(1): 89–96.

Rodriguez, C., Frias, J., Vidal-Valverde, C. and Hernandez, A. 2008. Correlations between some nitrogen fractions, lysine, histidine, tyrosine, and ornithine contents during the germination of peas, beans, and lentils. Food Chemistry 108 (1): 245-252.

Rimsten, L., Haraldsson, A.-K., Andersson, R., Alminger, M., Sandberg, A.-S. And Aman, P. 2003. Effects of malting on beta-glucanase and phytase activity in barley grain. Journal of the Science of Food and Agriculture 82(8): 904–912.

Sangronis, E., Rodriguez, M., Cava, R. and Torres, A. 2006. Protein quality of germinated *Phaseolus vulgaris*. European Food Research and Technology 222(1): 144-148.

Slavin, J., Jacobs, D. and Marquart L. 1997. Whole-grain consumption and chronic disease: protective mechanisms. Nutritional of Cancer 27(1): 4–21.

Suda, M., Watanabe, T., Kobayashi, M. and Matsuda, K. 1986. Changes in starch content and related enzyme activities during the growth of germinating soybeans. Agricultural and Biological Chemistry 50(12): 3195-3196.

Taira, H., Taira, H. and Maeshige, M. 1979. Influence of variety and crop year on lipid content and fatty acid composition of lowland non-glutinous brown rice. Japanese Journal of Crop Science 48(2): 220–228.

Tatsadjieu, N.L., Etoa F-X and Mbofung C.M.F. 2004. Drying Kinetics, Physicochemical and Nutritional Characteristics of "Kindimu", a Fermented Milk-Based-Sorghum-Flour. The Journal of Food Technology in Africa 9(1):17-22.

Tee, E.S., Kuladevan, R., Young, S.I., Khor, S.C. and Zakiyah, H.O. 1996. Nutrient analysis of foods. Kuala Lumpur: Institute Medical for Research.

Tharanathan, R.N. and Mahadevamma, S. 2003. Grain legumes-a boon to human nutrition. Trends in Food Science and Technology 14(12): 501-518.

Tonella M.L., Berry, J.W. 1987. Characteristics of a chocolate beverage from germinated chickpeas. Journal of Food Science 52(3): 726-728.

Torres, A., Frias, J., Granito, M. And Vidal-Valverde, C. 2007. Germinated *Cajanus cajan* seeds as ingredients in pasta products: Chemical, biological and sensory evaluation. Food Chemistry 101 (1) 202-211.

Urbano, G., Lopez-Jurado, M., Frejnagel, S., Gomez-Villalva, E., Porres, J.M., Frias, J., Vidal-Valverde, C. and Aranda, P. 2005. Nutritional assesment of raw and germinated pea (*Pisum Sativum* L.) protein and carbohydrate by in vitro and in vivo techniques. Nutrition 21 (2): 230-239.

Veluppillai, S., Nithyanantharajah, K. and Vasantharuba, S. 2009. Biochemical Changes Associated with Germinating Rice Grains and Germination Improvement. Rice Science 16(3): 240–242.

Vidal-Valverde, C., Frias, J., Sierra, I., Blazquez, I., Lambein, F. and Kuo, Y. 2002 New functional legume foods by germination: effect on the nutritive value of beans, lentils and peas. European Food Research and Technology 215(6): 472-477.

Wang, N., Lewis, M.J., Brennan, J.G. and Westby, A. 1997. Optimization of germination process of cowpea by response surface methodology. Food Chemistry 58(4):329-339.

Wilson, T.A., Ausman, L.M., Lawton, C.W., Hegsted, D.M. and Nicolosi, R.J. 2000. Comparative cholesterol lowering properties of vegetable oils: beyond fatty acids. Journal of American College of Nutrition 19 (5): 601- 607.

Yang, F., Basu, T.K. and Ooraikul, B. 2001. Studies on germination conditions and antioxidant contents of wheat grain. International Journal of Food Science and Nutrition 52(4): 319–330.

Yasmin, A., Zeb, A., Khalil, A.W., Paracha, G.M. and Khattak, A.B. 2008. Effect of processing on anti-nutritional factors of red kidney bean (*Phaseolus vulgaris*) grains. Food Bioprocess Technology 1(4): 415-419.

Yoshida, H., Hirakawa, Y., Murakami, C., Mizushina, Y. and Yamade, T. 2003. Variation in the content of tocopherols and distribution of fatty acids within soya bean seeds (*Glycine Max* L.). Journal of Food Composition and Analysis 16 (4): 429-440.

Yoshida, H., Hirakawa, Y., Tomiyama, Y., Nagamizu, T. and Mizushina, Y. 2004. Fatty acid distributions of triacylglycerols and phospholipids in peanut seeds (*Arachis hypogea* L.) following microwave treatment. Journal of Food Composition and Analysis 18 (1): 3-14.

Yoshida, H., Tomiyama, Y., Saiki, M. and Mizushima, Y. 2007. Tocopherol content and fatty acid distribution of peas (*Pisum Sativum* L.). Journal of the American Oil Chemists' Society 84(11): 1031-1038.

Yoshida, H., Tomiyama, Y., Yoshida, N., Saiki, M., and Mizushina, Y. 2008. Lipid classes, fatty acid distributions and triacylglycerol molecular species of broad beans (*Vicia Faba*). Journal of the American Oil Chemists' Society 85(6): 535-541.

Zhou, Z., Blanchard, C., Helliwell, S. and Robards, K. 2003. Fatty acid composition of three rice varieties following storage. Journal of Cereal Science 37(3): 327- 335.