Advance Journal of Food Science and Technology 12(5): 235-243, 2016
DOI:10.19026/ajfst.12.2905
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: September 22, 2015 Accepted: October 30, 2015 Published: October 15, 2016

Research Article

Physico-chemical and Antioxidant Properties of Eggplant Flour as a Functional Ingredient

[1]U. Uthumporn, [1]A. Fazilah, [1]A.Y. Tajul, [1]M. Maizura and [2]A.S. Ruri
[1]Food Technologi Division, School of Industrial Technologi, Universiti Sains Malaysia, 11800, Penang, Malaysia
[2]Politeknik LP31 Medan, JL. Amaliun No. 37, Medan Sumatera Utara, Indonesia

Abstract: Eggplant flour from different types of eggplant grown in Malaysia [Chinese eggplant (PL), Indian eggplant (PR), White eggplant (W) and Thailand eggplant (G)] had been produced by using oven drying, at 40 and 50ºC respectively. All eggplant showed the same trend for antioxidant properties following the order PR>PL>W>G. Among the eggplant grows in Malaysia, Indian eggplant flour which dried at 40ºC contained the highest amount of total phenolic content (3545.8 mg), total flavonoids content (2918.2 mg CAE/100 g), possessed the highest antioxidant activity by giving highest value in DPPH (92.70%) and FRAP assay. Higher drying temperature was found to inhibit the antioxidant activity of all types of eggplant flour except for white eggplant flour. All eggplant showed no significant changes in term of nutritional values. For Total Dietary Fiber (TDF) analysis, white eggplant flour had the highest content of total TDF (48.34%). which was 10x higher than in white wheat flour and 3x higher than in whole-grain wheat flour. Large portion of total dietary fiber in eggplant was found existed as insoluble fiber. Apparently, eggplant flour can be used as a functional ingredient in order to impart antioxidant and increase nutritional content of final products.

Keywords: Antioxidant, eggplant, flour, functional ingredient, phenolic content

INTRODUCTION

Food can provide nutritional support for our body while it can destroy life as well. Proper way of eating food can produce energy, maintain life, or stimulate growth while improper way of consuming food can cause disease. Taste is the major reason why consumers choose a particular food. Taste consistently outranks consumer's concern about the nutritional quality, especially in young people. They seem to be more attracted to the fancy flavoring and packaging rather than the nutritional value of the food itself. Unfortunately, good-tasting foods are often high in fats. High fat food can lead to many chronic diseases such as diabetes, hypertension and cardiovascular complications. Diet high in saturated fat is correlated with the incidence of coronary disease (Liu *et al*., 1982). A recent statistic reported that cardiovascular disease is now the leading cause of medically-certified deaths among Malaysian women, with one in four dying of heart failure (Brighenti *et al*., 2013).

A great number of research activities have demonstrated a significant correlation between the regular intakes of phytochemicals and the prevention of life-style related diseases such as cardiovascular diseases, arteriosclerosis and obesity (Gresele *et al*., 2011). Phytochemicals including polyphenol compounds, other nutrients and non-nutrient compounds (minerals, vitamins and dietary fiber) are the components in plants that confer health promoting abilities (Gonzáles-Molina *et al*., 2010). These beneficial ingredients of fruits and vegetables can be extracted and serve as the functional ingredients in producing functional food with added dietary value.

According to Hasler *et al*. (2000), functional food is defined as food that consists of added physiological active compounds that provides health benefit beyond basic nutrition. Functional food is also known as conventional food that enriched with bioactive substances such as antioxidants or synthesized food ingredients such as prebiotics (Choudhary and Tandon, 2009).

Solanum melongena L. commonly known as eggplant, aubergine, guinea squash or brinjal, is an economically important vegetable crop of tropical and temperate parts of the world (Kashyap *et al*., 2003). Eggplant can exist in different shapes, sizes and colors, depending on the cultivar. Eggplant fruits usually are purple, white or striped in color. The coloration of the purple color type eggplant fruit is caused by the presence of anthocyanin, where the purple one is commercially more important.

Corresponding Author: U. Uthumporn, Food Technology Division, School of Industrial Technologi, Universiti Sains Malaysia, 11800, Penang, Malaysia, Tel.: +604-6532220; Fax: +604-6573678

Eggplant is ranked as one of the top ten vegetables due to its high oxygen radical scavenging capacity (Jung *et al*., 2011). According to Lintas (1992), eggplant is also rich in dietary fibers. According to Jacob *et al*. (2012), antioxidant capacity is one of the common features of functional ingredient. Hence, eggplant is suggested to use as a functional ingredient in producing functional food with added nutritional value. Therefore, the objective of this research is to determine the nutritional contents, the antioxidant capacity and total dietary fiber in different varieties of eggplant flour produced, which are grown solely in Malaysia.

MATERIALS AND METHODS

Plant material: Four varieties of eggplant were purchased from market and Tesco supermarket in Penang. The eggplants purchased were fresh and free from physical damage. There are Chinese Eggplant (purple color and long shape), Indian Eggplant (purple color, moderate size and oval shape), white eggplant (white color, moderate size and oval in shape) and Thai eggplant (green color, small size and round in shape).

Preparation of eggplant flour: The eggplants were washed thoroughly under running tab water to remove soils and foreign particles. They were cut into slices without peeling off the skin by using electrical slicer, so that they were in uniform thickness and size. Each type of eggplant was dried at two temperatures, which is 40 and 50°C in hot air oven (AFOS Dryer) for 72 h. The dried eggplants were grinded into powder form by using heavy duty blender (Juicemaking Blender, BL-767) and sieved through 250 μm siever on a shaker (Retsch Vibrator Stever Shaker, AS 200 BASIC). All grounded samples were packed into plastic bag. They were sealed properly and wrapped with aluminum foil to protect the samples from light. Then, they were stored in a freezer at -20°C.

Proximate analysis:

Moisture: Moisture content of sample was determined by using moisture analyzer (AND MX-50). The results are recorded as % of moisture content.

Ash: Dry ashing method from AOAC (2000), Method 923.03 was referred to analyze the content of ash.

Crude protein: Crude protein content was determined by using protein analyzer (Protein Analysis System Gerhardt, KB 205), following the 960.52 in the AOAC (2000).

Fat: Soxhlet method, method 960.39C in AOAC (2000) was used to determined fat content in samples.

Crude fiber: Gravimetric method which is method 962.09 of AOAC (2000) was used to determine crude fiber.

Carbohydrate: The content of carbohydrate was not determined through any chemical analysis but through calculation. The content of carbohydrate (dry basis) was determined through the following equation:

% Carbohydrates (dry basis) = 100%- Moisture% - Fat%-Protein%-Ash%

Sample extraction for determination of antioxidant activity: Extraction of sample was carried out with modification according to the method by Fu *et al*. (2011). 1 g of sample was weighted into a conical flask which wrapped with aluminum foil and 100 mL of 80% methanol was added into the flask. The mixture was shaken for 24 hours at 160 rpm, at 27°C with an orbital shaker (Lab Companion, Model SI600R). The mixture was then centrifuged at 2500 rpm for 30 minutes (KUBOTA 5100 Centrifuge, Japan) in order to obtain a clear supernatant. The supernatant was used for further determination of phenolic content and antioxidant capacity.

Determination of Total Phenolic content (TP): TP content of the sample extract was determined by FC assay with slightly modification of the method described by Singleton and Rossi (1965). 2 mL of 10 times pre-diluted FC reagent was mixed with 400 μL properly diluted sample extract and the mixture was allowed to stand for 5 minutes at room temperature. After that, 1.6 mL of 7.5% w/v sodium carbonate solution was added. The solution was mixed and allowed to stand at room temperature for 1 hour. The absorbance was then measured at 765 nm. A standard curve was prepared by using gallic acid solution. Standard curve was prepared by using standard solution of gallic acid with known concentration (0, 20, 40, 60, 80, 100 mg/L; r^2 = 0.995, refer appendix A for the standard curve). The results obtained were expressed as weight basis as mg Gallic Acid Equivalents (GAE) /100 g of sample.

Determination of Total Flavonoids content (TF): Colorimetric assay developed by Zhishen *et al*. (1999) was referred and some modification has done onto the method in order to determine TF content. 1 mL of properly diluted sample extract was mixed with 4 mL of distilled water and at zero time, 300 μL of (5% w/v) sodium nitrite ($NaNO_2$) was added. After 5 min, 300 μL of (10%) Aluminium Chloride ($AlCl_3$) was added. At 6 minutes, 2 mL of 1 M of NaOH solution was added and then the volume of the mixture was made up immediately by addition of 2.4 mL of distilled water to 10 mL. The mixture was shaken vigorously and the absorbance was read at 510 nm against blank. Blank was prepared by 1 mL of distilled water instead of diluted sample extract. A standard curve was prepared by using catechin solution. Standard curve was prepared by using standard solution of catechin with known concentration (0, 20, 40, 60, 80, 100 mg/L; r^2 =

0.998, refer appendix B for standard curve). The results obtained were expressed as weight basis as mg Catechin Equivalents (CEQ)/100g of sample.

DPPH free radical-scavenging assay: The determination of the antioxidant activity through the evaluation of the free radicals scavenging effect on DPPH was based on the slight modification of method done by Xu and Chang (2007). An aliquot (1 mL) of sample extract was mixed with 6 mL of DPPH solution. Negative control was prepared by mixing 1 mL of methanol with 6 mL of DPPH solution. All the mixtures to be tested were prepared in test tubes with lid, which were wrapped with aluminum foil. The mixture was vortexed and kept in the dark for 30 minutes at room temperature. Absorbance was measured at 517 nm wavelength using UV-Vis spectrophotometer (Shimadzu UV-Visible Recording Spectrophotometer Model UV-160A) against blank. The results obtained were calculated and expressed in the term of % DPPH inhibition by using the formula below: ($A_{control}$ = absorbance of control; A_{sample} = absorbance of sample):

$$\%\text{inhibition of DPPH} = [(A_{control}-A_{sample})/A_{control}] \times 100\%$$

Ferric Reducing Antioxidant Power (FRAP) assay: A modified method of FRAP assay was carried out based on the method proposed by Benzie and Strain (1999). An aliquot amount of 200 µL properly diluted sample extract was mixed with 3mL of FRAP reagent, whereas for blank sample distilled water is mixed with FRAP reagent instead of sample extract. The mixture was then incubated in water bath at 37°C for 30 min. After 30 min, the absorbance of sample was determined against blank at 593 nm wavelength. A standard curve was prepared by using the aqueous solution of aqueous ferrous sulphate heptahydrate ($FeSO_4$. $7H_2O$) with known concentration (0, 200, 400, 600, 800 µM; r^2 = 0.996, refer appendix for the standard curve). The values obtained were expressed on weight basis as micromoles of ferrous equivalent Fe (II) per gram of dried sample.

Total Dietary Fiber (TDF) analysis: Enzymatic and gravimetric methods following AOAC (2000) method 985.29 and 960.52 was used in TDF analysis.

Statistical analysis: The results of the present study were represented as mean values±SD. One way analysis of variance (ANOVA) was performed and significant differences between mean values were determined by Duncan test at a level of significance of $p<0.05$. Statistical analysis were conducted using SPSS (Statistical Package for Social Science) version 17.0 (SPSSInc., Chicago, USA).

RESULTS AND DISCUSSION

The eggplant flour produced were labelled as PR 40 (Indian eggplant dried at 40°C); PR 50 (Indian eggplant dried at 50°C); G 40 (Thai eggplant dried at 40°C); G 50 (Thai eggplant dried at 50°C); PL 40 (Chinese eggplant dried at 40 °C); PL 50 (Chinese eggplant dried at 50°C); W 40 (white eggplant dried at 40°C) and W 50 (white eggplant dried at 50°C).

Proximate analysis: Nutritional analysis of four different varieties of eggplant was carried out on dry basis and it was reported in the Table 1. The moisture content of all types of eggplant flour obtained was in the range of 8.47-9.45%. Sample PR 40 had the highest moisture, while sample G 50 had the lowest moisture content. Moisture content that we obtained is found to be higher than the result of moisture reported by Hussain *et al*. (2011). This is due to the fact that higher temperature was used in the research by Hussain *et al*. (2011). All samples that were subjected to 40°C drying temperature had higher moisture content compared to the samples subjected to 50°C.

The highest ash content was obtained from sample W 50 (8.73%) and the lowest content was obtained from sample G 40 (8.13%). Ash content of eggplant reported by Hussain *et al*. (2011) was 8.9%, which was comparable to the ash content obtained in our research. Eggplants of white variety (W 40 and W50) were found to be consisting higher amount of minerals due to the higher ash content among all the varieties. Ash content represents the mineral contents in food because ash is the inorganic residues left over after complete ignition or oxidation of organic compounds in food (Harbers and Nielsen, 2003). Calcium, magnesium, phosphorus, potassium, iron and sodium are some of the major minerals that contained in eggplant. Savvas

Table 1: Proximate compositions (g/100 g) of various types of eggplant flour

Samples	Moisture	Ash	Fat	Protein	Crude fiber	Carbohydrate
PR 40	9.45 ± 0.15^{b}	8.14 ± 0.09^{a}	2.34 ± 0.16^{d}	12.98 ± 0.06^{a}	14.29 ± 0.58^{b}	67.10 ± 0.13^{f}
PR 50	9.11 ± 0.18^{b}	8.24 ± 0.04^{a}	1.21 ± 0.08^{b}	15.63 ± 0.04^{f}	14.13 ± 0.33^{b}	65.81 ± 0.23^{d}
G 40	9.42 ± 0.05^{b}	8.13 ± 0.04^{a}	5.18 ± 0.05^{h}	14.53 ± 0.03^{d}	13.56 ± 0.33^{a}	62.73 ± 0.07^{a}
G 50	8.47 ± 0.43^{a}	8.24 ± 0.02^{a}	2.75 ± 0.04^{f}	15.20 ± 0.11^{e}	13.19 ± 0.42^{a}	65.34 ± 0.51^{c}
PL 40	8.60 ± 0.05^{a}	8.46 ± 0.06^{b}	1.48 ± 0.04^{f}	13.40 ± 0.02^{b}	15.66 ± 0.25^{c}	68.07 ± 0.04^{g}
PL 50	8.58 ± 0.39^{a}	8.42 ± 0.05^{b}	0.88 ± 0.02^{a}	15.75 ± 0.05^{g}	15.77 ± 0.38^{c}	66.37 ± 0.29^{e}
W 40	8.67 ± 0.12^{a}	8.52 ± 0.07^{b}	4.23 ± 0.09^{g}	14.52 ± 0.03^{d}	18.67 ± 0.38^{d}	64.05 ± 0.06^{b}
W 50	8.64 ± 0.09^{a}	8.73 ± 0.14^{c}	2.51 ± 0.03^{e}	13.55 ± 0.02^{c}	19.00 ± 0.66^{d}	66.57 ± 0.21^{e}

Data is expressed as mean±standard deviation (n = 3); means in column sharing the same superscript letter are not significantly different ($p<0.05$); PR: Purple Round/Oval; Eggplant (Indian Eggplant); G: Green Long Eggplant (Thai Eggplant); PL: Purple Long Eggplant (Chinese Eggplant): W: White Eggplant

Table 2: Insoluble dietary fiber, soluble dietary fiber and total dietary fiber content in various types of eggplant flour

Samples	IDF (%)	SDF (%)	TDF (%)
PR 40	26.87±1.312[b]	6.22±0.080[b]	33.09±1.291[a]
PR 50	27.08±0.804[b]	8.19±0.110[d]	35.26±0.748[b]
G 40	36.83±0.343[c]	7.23±0.170[c]	44.07±0.377[e]
G 50	37.37±0.531[c]	5.68±0.229[a]	43.05±0.717[e]
PL 40	25.31±0.612[a]	11.86±0.227[f]	37.18±0.428[c]
PL 50	28.01±1.165[b]	12.28±0.396[g]	40.97±0.136[d]
W 40	39.19±0.595[d]	7.02±0.121[c]	46.21±0.508[f]
W 50	39.32±0.128[d]	9.01±0.235[e]	48.34±0.360[g]

Data is expressed as mean±standard deviation (n = 3); Means in column sharing the same superscript letter are not significantly different (p<0.05); PR: Purple Round/Oval; Eggplant (Indian Eggplant); G: Green Long Eggplant (Thai Eggplant); PL: Purple Long Eggplant (Chinese Eggplant); W: White Eggplant

and Lenz (1996) also found that eggplant provide relevant quantities of some minerals such as phosphorus, potassium, calcium and magnesium.

For fat determination, the results obtained fell on a big range of 0.88-5.18%. Our results are in accordance with the work by Lawande and Chavan (1998). They have reported that fat content for eggplant range about 0.33-5.20%. Sample G 40 showed the highest fat content (5.18%) and followed by sample W 40 (4.23%); sample PL 50 had the lowest fat content (0.88%) and PR 50 had the second lowest fat content (1.21%). The results obtained indicated that different types of eggplant have different fat content, which was in agreement with the previous study by Nisha *et al.* (2009).

Sample PL 50 had the highest amount of protein, which was 15.75% whereas sample PR 40 had the lowest amount of protein, which was 12.98%. Results of protein content obtained from all four varieties of eggplant are higher compared to the work by Hussain *et al.* (2011), which was about 9.7% of protein content. This may due to the different fertilizers used by the farmers in Malaysia to cultivate the eggplants. According to Mut *et al.* (2010), the addition of animal manure as fertilizer to soil can increase the protein content of plants. Considerable increases in protein content of plants with increasing nitrogen application also observed by some of the researchers (Behrens *et al*., 2001; Rathke *et al*., 2005).

For Crude Fiber (CF) analysis, sample W 50 contained 19.0% of CF, which was the highest amount compared to other varieties. While, sample G 50 contained the lowest CF among all varieties, which was 13.19%. Our results also showed that different drying temperature had no effect on the crude fiber content.

PL 40 was found to show the highest carbohydrate content, whereas G 40 had the lowest carbohydrate content, which was 68.07 and 62.73%, respectively. Results of the present investigation are similar to the carbohydrate content obtained by Hussain *et al*. (2011). Eggplant flour gave the highest value in carbohydrate content among all the proximate analysis, which indicated that eggplant, is made up of large portion of carbohydrates. Vegetables are composed primarily of carbohydrates, which are chiefly in the form of simple sugars and complex carbohydrates (Lintas, 1992).

The showed that eggplant flour had high nutritional value and it is a better source for minerals, natural fats, protein and crude fiber. Eggplant flour contained lower amount of moisture and carbohydrate. There is an inverse relationship between moisture content and storage stability of flour, as lower the moisture content of flour, the better its storage stability. An investigation also found that flour with the lowest moisture content had the maximum resistance against fungal growth and pest infestation during storage. Flour having moisture content of 9% to 10% is suitable for extended shelf life (Nasir *et al*., 2003). Hence, it was believed that eggplant flour produced could have greater shelf life and higher storage stability compared to wheat flour due to the lower moisture content.

Total dietary fiber analysis: Table 2 shows the insoluble dietary fiber, soluble dietary fiber and total dietary fiber content of all the four varieties of eggplant flours. Dietary fibers in all the four types of eggplant flours were higher compared to Wheat Flour (WF) and whole Wheat Flour (WG) (FrØLich and Asp, 1981).

IDF of eggplant flours ranged from 25.31-39.32%, and it was approximately ten times higher than the amount of IDF in WF and two times higher than the IDF amount in WG. SDF of eggplant flours ranged from 5.68-12.28%. SDF content in WF and WG were significantly lower than in eggplant flours. For TDF content, eggplant flours contained more than ten times of the amount in WF and more than three times the amount in WG. Therefore, eggplant flour should be considered to be used as a functional ingredient in producing healthy food. Based on earlier investigation Wolever (1990), total dietary fiber was positively related to Glycemic Index (GI), in which the soluble fiber did not show significant relationship with GI, while insoluble fiber had the most significant relationship with GI. By reducing dietary GI and maintaining high dietary fiber intake could reduce the risk of type 2 diabetes (Hodge *et al*., 2004). There was also study showed high intake of dietary fiber lead to the lower BMI (Murakami *et al*., 2007).

According to the results in Table 2, the ascending order of the amount of TDF was PR 40 (33.09%) <PR 50 (35.26%)<PL 40 (37.18%)<PL 50 (40.97%)<G 50 (44.07%)<G 40 (43.05%)<W 40 (46.21%)<W 50(48.34%). TDF had the same trend as in IDF content in this study. Research of Khanum *et al.* (2000) found fresh eggplant contributes 83% of IDF in TDF of fresh eggplant. The high amount of TDF obtained suggests

Table 3: Total phenolic content, total flavanoids content and antioxidant capacity of various types of eggplant flour

Eggplant	Total phenolic content (mg GAE/g fresh weight)	Total flavanoids (mg CEQ/g fresh weight)	FRAP (µmol Fe (II)/ g fresh weight)	(%) DPPH inhibition
PR 40	2918.1±35.1^{g}	2918.2±89.3^{g}	624.5±11.2^{h}	92.7±1.5^{e}
PR 50	2082.2±21.1^{f}	2219±52.6^{f}	484.7±10.9^{g}	89.1±1.8^{d}
G 40	2043.2±18.4^{c}	1294.3±11.4^{b}	377.5±5.2^{d}	87.3±1.1^{c}
G 50	1184.3±11.8^{a}	1158.2±5.6^{b}	211.9±8.3^{a}	82.6±1.6^{a}
PL 40	1953.7±10.2^{e}	1982±68.9^{e}	466.4±9.1^{f}	89.1±0.9^{d}
PL 50	1791.4.3±24.1^{d}	1781±76.2^{d}	409.7±7.5^{e}	87.8±0.7^{c}
W 40	1819.1±13.7^{b}	909.4±13.7^{a}	287.5±7.7^{b}	85.9±0.4^{b}
W 50	2010.9±12.9^{c}	1294.3±15.4^{c}	353.1±3.4^{c}	87.3±1.7^{c}

Data is expressed as mean±standard deviation (n = 3); Means in column sharing the same superscript letter are not significantly different (p<0.05); PR: Purple Round/Oval; Eggplant (Indian Eggplant); G: Green Long Eggplant (Thai Eggplant); PL: Purple Long Eggplant (Chinese Eggplant); W: White Eggplant

that consuming foods that were produced from eggplant flour is able to prolong the feeling of fullness because the bulking properties of dietary fiber can affect satiation and satiety (Burton-Freeman, 2000). The TDF content of all types of eggplant flours was higher when compared to WF and WG (FrØLich and Asp, 1981). This is further confirmed by the identical trend observed in crude fiber and TDF. Therefore, it is believed that eggplant flour can be used as a functional ingredient and be incorporated to produce functional or fiber fortified food.

Total phenolic content: Phenolic solubility in different types of extraction solvent can influence the recovery of type and amount of phenolics from plants. The phenolic extracts of plants are always a mixture of different classes of phenols, which are selectively soluble in the solvents. Methanol was selected as the solvent for phenolics extraction. Some previous investigations had concluded that methanol extraction had greater recovery of phenolics (Shi *et al*., 2005; Chirinos *et al*., 2007). Methanol is efficient and effective in extracting phenolics such as hydroxycinnamic derivatives, flavonols, flavan 3-ol monomers, flavanones and flavones (Chirinos *et al*., 2007). According to Mohammadi *et al*. (2008), the usage of alcoholic solution as a solvent in the isolation of phenolic compounds of plants gave satisfactory yield.

Table 3 showed the Total phenolic of all the four samples measured by using FC reagent. TP of the eggplant flours ranged from 1184.3-2043.2 mg GAE/100 g for G, while it ranged from1819..1-2010.9 mg GAE/100 g for W, from 2414.6- 2265.3 mg GAE/100 g for PL and from 2652.7-3545.8 mg GAE/100 g for PR. The highest TP was shown by PR 40 (3545.8 mg GAE/100 g) while the lowest was shown by G 50 (1184.3 mg GAE/100 g). These results are significantly higher than the earlier observation of TP on different eggplant varieties by Nisha *et al*. (2009) because the eggplant flours used in this present were produced without removing the peel. Eggplant peel contains significant amount of phenolic compound (Jung *et al*., 2011) such as anthocyanin. Anthocyanin is a natural pigment that gives purple or red color to fruits or peel (Mazza *et al*., 2004). Nasunin or identified as delphinidin-3-(*p*-coumaroylrutinoside)-5-glucoside by Sakamura *et al*. (1963) is the major component of anthocyanin pigment in eggplant peel (Noda *et al*., 2000). The health benefits of the natural phenolic components present in vegetables are mainly attributed to their antioxidant activity. According to Huang *et al*. (2004), phenolic content of eggplant peel is approximately two fold higher than in eggplant pulp. Caffeic, p-coumaric, ferulic, gallic, protocatechuic and p-hydroxybenzoic acids were some of the phenolic phytochemicals that found in eggplant fruits.

The results also show significant differences in TP between samples that were dried at two different temperatures. Samples PR, G, PL that was dried at 40 ºC had higher TP than samples that were dried at 50ºC. This could be attributed to the heat sensitivity of antioxidant. High drying temperature can cause degradation of antioxidant. However, W did not show the consistent trend of the effect of drying temperature on TP as PR, PL and G. The different trend of the drying temperature effect on samples W suggests that the effect of thermal processing on phenolic activities may vary in some eggplant varieties.

Total flavonoids content: The TF of different eggplant flours are shown in Table 2. TF content follows the order PR>PL>G>W. TF content in both purple varieties (PR and PL) was found to be higher than the W and G. Previous observation had found that purple-colored eggplant had higher TP and TF content than the white-green colored eggplant, pale green eggplant and long green eggplant (Akanitapichat *et al*., 2010). According to the results, drying temperature showed a significant difference on TF where higher drying temperature gave lower TF, except for W. The decrease of TF level in flour subjected to higher drying temperature could be due to part of the anthocyanin had been degraded during heating. Generally, treatment at higher temperature can influence level of anthocyanin in fruits and vegetables. According to Schieber *et al*. (2001), the loss of macromolecules such as flavonoid during heat treatment might be due to the drying conditions, which are the temperature and duration used. However, the trend shown by the effect of drying temperature on the TF was inconsistent. This could be due to the different varieties of eggplant used in this study.

DPPH free radical scavenging assay: DPPH solution change color from purple to yellow when the DPPH radical is scavenged by antioxidants (Karagözler *et al*., 2008). Antioxidants act as hydrogen donors when react with DPPH radical, where the hydrogen from radical scavenging antioxidant pairs with the odd electron of DPPH. DPPH radical is then reduced to DPPH-H and decreases the absorbance. The scavenging ability of antioxidant is based on the hydrogen donating ability which causes discoloration of DPPH solution (Razak, 2012).

Table 2 shows the DPPH scavenging activities of all the four different samples. It follows the order of PR>PL>W>G. Antioxidant activity of PR was remarkably higher than the other three samples. The low DPPH scavenging activity showed by G is similar with the results of previous research by Akanitapichat *et al*. (2010). According to Shahidi *et al*. (2011), delphinidin-3-caffeoylrutinoside-5-glucoside was a major component in anthocyanin of eggplant that found to be possessed the highest radicals scavenging activity towards DPPH.

All samples show significant differences in drying temperature on the DPPH inhibition. This indicates that drying temperature can influence the capability of antioxidants present in eggplant to inhibit DPPH radical. Higher drying temperature caused a decrease in DPPH scavenging activity in PR, G and PL. This could be due to thermal degradation of some antioxidant in eggplant such as ascorbic acid and anthocyanin. As in earlier study of tomato, the higher drying temperature decreased the value of ascorbic acid in tomato, *Solanum lycopersicum* (Idah *et al*., 2010). However, higher temperature caused an increase in DPPH inhibition capability in W could due to the formation of polyphenolic degradation products from the thermal destruction of anthocyanin. These products formed may possess antioxidant activity. Nonetheless, there is still limited information available on the temperature stability of anthocyanin and the products formed in the thermal degradation of anthocyanins.

FRAP assay: FRAP assay is commonly used to study the antioxidant capacity of plant materials by measuring the reducing ability of an antioxidant. FRAP assay depends on the reduction of a ferric tripyridyltriazine, Fe $(TPTZ)_2$ (III) complex to the ferrous tripyridyltriazine, $Fe(TPTZ)_2$(II) complex by an antioxidant in acidic medium, at a low pH of 3.6. This reduction process produces intense blue complex that has absorption at 593nm (Moon and Shibamoto, 2009). Reduction capability of ferric ion can be monitored by measuring the change in absorption at 593 nm.

Antioxidant capacity that analyzed by FRAP assay had identical trend as the DPPH free radical-scavenging assay. Based on Table 2, similarly, samples PR had the highest FRAP value, from 484.7-624.5 μmole Fe (II)/g sample, followed by PL, from 409.7-466.4 μmole Fe (II)/g sample; W, from 287.5-353.1 μmole Fe (II)/g sample and G, from 211.9-377.5 μmole Fe (II)/g sample. The identical trend in DPPH and FRAP assay could be due to the reaction mechanism of DPPH and FRAP are similar with each other, which involves the reduction activity and reduction ability of antioxidants on certain compounds, which are DPPH· radical and ferric ions (Alothman *et al*., 2009). This is understandable as both DPPH and FRAP assays are based on electron-transfer reaction.

Not only DPPH and FRAP analysis share the identical trend, but the same trend was also observed in TP and TF of all these four varieties of eggplant flour. Results obtained show the strong association between high antioxidant activity and phenolic content as this has been previously verified in eggplant by Noda *et al*. (2000) and Huang *et al*. (2004). The same trend in TP, DPPH and FRAP was also on a par with the earlier investigation on eggplant from different varieties (Razak, 2012). Therefore, it can be concluded that phenolic compounds serve as the main constituents that contribute to the antioxidant properties in eggplant flour. On the other hand, the same trend in TF suggests that flavonoids are the most important phenolic group that contributes to the antioxidant activities of eggplant. Flavonoids that can be found in eggplant are delphinidin-3-(p-coumaroylrutinoside) - 5-glucoside, delphinidin-3-rutinoside, delphinidin-3-glucoside, petunidin-3-(p-coumaroylrutinoside)-5-glucoside and delphinidin- 3-caffeoylrutinoside-5-glucoside (Azuma *et al*., 2008), myricetin-3-galactoside, quercetin-3-galactoside and quercetin-3-rhamnoside (Singh *et al*., 2009).

CONCLUSION

The explosion of consumer interest in the relationship between diet and health has increased the demand for information on functional foods. Functional foods that have been identified as to be beneficial are foods containing phytochemicals, fibre, minerals and vitamin containing foods. The exploration of the properties of dietary phytochemicals in traditional and indigenous fruits and vegetables is important to develop new resources to serve as functional ingredients in producing value-added food in acquiring optimized health.

This current study involved the determination of the nutritional values, extraction of antioxidants, analyzing of antioxidant capacity and the determination of TDF content in different varieties of eggplant flour as we believed that eggplant flour can be used as new resource to serve as functional ingredient in preparation of functional foods. Different varieties of eggplant flour consisted of different nutritional composition. Drying temperature did not show any effect on the crude fiber of eggplant flour. On the other hand, the level of ash, protein, fat and crude fiber in most of the eggplant floor in this study were found to be higher than in WF and WG.

The results obtained clearly showed that eggplant flour possess the ability to scavenge the free radicals which is carcinogenic to human body due to the presence of antioxidants. Flour produced from eggplant of purple varieties consisted of higher level of antioxidant compared to other varieties. Drying temperature did affect on the antioxidant capacity as we know that antioxidant is heat sensitive. However, the effect of drying temperature on antioxidant capacity also depends on the types of eggplant.

PL eggplant was most the suitable eggplant that can be used to obtain flour with better quality for the use in food application or in high fiber food for health promotion. The ideal drying temperature used was 40ºC. This is because PL 40 was low in fat, moderate in protein, ash and antioxidant activity compared to others. Lastly, it can be concluded that eggplant flour can be used as a functional ingredient in the processing of functional food which is not only high in TDF but also high in antioxidant and nutritional value.

ACKNOWLEDGMENT

This project has been supported by University Sains Malaysia; Short term grant.

Conflict of interest: The authors declare no conflict of interest.

REFERENCES

Akanitapichat, P., K. Phraibung, K. Nuchklang and S. Prompitakkul, 2010. Antioxidant and hepatoprotective activities of five eggplant varieties. Food Chem. Toxicol., 48(10): 3017-3021.

Alothman, M., R. Bhat and A.A. Karim, 2009. Antioxidant capacity and phenolic content of selected tropical fruits from Malaysia, extracted with different solvents. Food Chem., 115(3): 785-788.

AOAC, 2000. Official Methods of Analysis. 17th Edn., Association of Official Analytical Chemists, Arlington, VA, USA.

Azuma, K., A. Ohyama, K. Ippoushi, T. Ichiyanagi, A. Takeuchi, T. Saito and H. Fukuoka, 2008. Structures and antioxidant activity of anthocyanins in many accessions of eggplant and its related species. J. Agr. Food Chem., 56(21): 10154-10159.

Behrens, T., W.J. Horst and F. Wiesler, 2001. Effect of Rate, Timing and Form of Nitrogen Application on Yield Formation and Nitrogen Balance in Oilseed Rape Production. In: Horst, W.J., M.K. Schenk, A. Bürkert *et al*., Plant Nutrition: Food Security and Sustainability of Agro-ecosystems through Basic and Applied Research. Kluwer Academic Publishers, Dordrecht, 92: 800-801.

Benzie, I.F. and J.J. Strain, 1999. Ferric reducing/antioxidant power assay: Direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration. Method. Enzymol., 299: 15-27.

Burton-Freeman, B., 2000. Dietary fiber and energy regulation. J. Nutr., 130: 272S-275S.

Chirinos, R., H. Rogez, D. Campos, R. Pedreschi and Y. Larondelle, 2007. Optimization of extraction conditions of antioxidant phenolic compounds from mashua (*Tropaeolum tuberosum* Ruíz & Pavón) tubers. Sep. Purif. Technol., 55(2): 217-225.

Choudhary, R. and R.V. Tandon, 2009. Consumption of functional food and our health concerns. Pak. J. Physiol., 5: 76-83.

FrØLich, W. and N.G. Asp, 1981. Dietary fiber content in cereals in Norway. Cereal Chem., 58(6): 524-527.

Fu, L., B.T. Xu, X.R. Xu, R.Y. Gan, Y. Zhang, E.Q. Xia and H.B. Li, 2011. Antioxidant capacities and total phenolic contents of 62 fruits. Food Chem., 129(2): 345-350.

Gonzáles-Molina, E., R. Domínguez-Perles, D.A. Moreno and C. García-Viguera, 2010. Natural bioactive compounds of *Citrus limon* for food and health. J. Pharmaceut. Biomed., 51(2): 327-345.

Gresele, P., C. Cerletti, G. Guglielmini, P. Pignatelli, G. de Gaetano and F. Violi, 2011. Effects of resveratrol and other wine polyphenols on vascular function: An update. J. Nutr. Biochem., 22(3): 201-211.

Harbers, L.H. and S.S. Nielsen, 2003. Ash Analysis. In: Nielsen, S.S. (Ed.), 3rd Edn., Food Analysis. Kluwer Academic/Plenum Plublishers, New York, pp: 103-111.

Hasler, C.M., S. Kundrat and D. Wool, 2000. Functional foods and cardiovascular disease. Curr. Atheroscler. Rep., 2(6): 467-475.

Hodge, A.M., D.R. English, K. O'Dea and G.G. Giles, 2004. Glycemic index and dietary fiber and the risk of type 2 diabetes. Diabetes Care, 27: 2701-2706.

Huang, H.Y., C.K. Chang, T.K. Tso, J.J. Huang, W.W. Chang and Y.C. Tsai, 2004. Antioxidant activities of various fruits and vegetables produced in Taiwan. Int. J. Food Sci. Nutr., 55: 423-429.

Hussain, J., N.U. Rehman, A.L. Khan, H. Hussain, A. Al-Harrasi, L. Ali, F. Sami and Z.K. Shinwari, 2011. Determination of macro and micronutrients and nutritional prospects of six vegetable species of Mardan, Pakistan. Pak. J. Bot., 43(6): 2829-2833.

Idah, P.A., J.J. Musa and S.T. Olaleye, 2010. Effect of temperature and drying time on some nutritional quality parameters of dried tomatoes. AU J. Technol., 14(1): 25-32.

Jacob, J.K., K. Tiwari, J. Correa-Betanzo, A. Misran, R. Chandrasekaran and G. Paliyath, 2012. Biochemical basis for functional ingredient design from fruits. Annu. Rev. Food Sci. Technol., 3: 79-104.

Jung, E.J., M.S. Bae, E.K. Jo, Y.H. Jo and S.C. Lee, 2011. Antioxidant activity of different parts of eggplant. J. Med. Plants Res., 5(18): 4610-4615.

Karagözler, A.A., B. Erdağ, Y.C. Emek and D.A. Uygun, 2008. Antioxidant activity and proline content of leaf extracts from *Dorystoechas hastata*. Food Chem., 111: 400-407.

Kashyap, V., S. Vinod Kumar, C. Collonnier, F. Fusari, R. Haicour, G.L. Rotino, D. Sihachakr and M.V. Rajam, 2003. Biotechnology of eggplant. Sci. Hortic-Amsterdam, 97(1): 1-25.

Khanum, F., M. Siddalinga Swamy, K.R. Sudarshana Krishna, K. Santhanam and K.R. Viswanathan, 2000. Dietary fiber content of commonly fresh and cooked vegetables consumed in India. Plant Food Hum. Nutr., 55(3): 207-218.

Lawande, K.E. and J.K. Chavan, 1998. Eggplant (Brinjal). In: Salunkhe, D.K. and S.S. Kadam (Eds.), Handbook of Vegetable Science and Technology: Production, Composition, Storage and Processing. Marcel Dekker, New York, pp: 225-244.

Lintas, C., 1992. Nutritional aspects of fruit and vegetable consumption. In: Lauret, F. (Ed.), Les fruits et légumes dans les économies méditerranéennes: actes du colloque de Chania. (Options Méditerranéennes: Série A. Séminaires Méditerranéens; n. 19). CIHEAM, Montpellier, pp: 79-87.

Liu, K., J. Stamler, M. Trevisan and D. Moss, 1982. Dietary lipids, sugar, fiber and mortality from coronary heart disease. Bivariate analysis of international data. Arteriosclerosis, 2(3): 221-227.

Mazza, G., J.E. Cacace and C.D. Kay, 2004. Methods of analysis for anthocyanins in plants and biological fluids. J. AOAC Int., 87(1): 129-145.

Mohammadi, A., S. Rafiee, A. Keyhani and Z. Emam-Djomeh, 2008. Estimation of thin-layer drying characteristics of kiwifruit (cv. Hayward) with use of Page's model. Am-Eurasian J. Agr. Environ. Sci., 3(5): 802-805.

Moon, J.K. and T. Shibamoto, 2009. Antioxidant assays for plant and food components. J Agr. Food Chem. 57: 1655-1666.

Murakami, K., S. Sasaki, H. Okubo, Y. Takahashi, Y. Hosoi and M. Itabashi, 2007. Dietary fiber intake, dietary glycemic index and load, and body mass index: A cross-sectional study of 3931 Japanese women aged 18-20 years. Eur. J. Clin. Nutr., 61(8): 986-995.

Mut, H., I. Ayan, U. Basaran, O. Onal-Asci and Z. Acar, 2010. The effects of sheep manure application time and rates on yield and botanical composition of secondary succession rangeland. Afr. J. Biotechnol., 9(23): 3388-3395.

Nasir, M., M.S. Butt, F.M. Anjum, K. Sharif and R. Minhas, 2003. Effect of moisture on the shelf life of wheat flour. Int. J. Agric. Biol., 5(4): 458-459.

Nisha, P., P.A. Nazar and P. Jayamurthy, 2009. A comparative study on antioxidant activities of different varieties of *Solanum melongena*. Food Chem. Toxicol., 47(10): 2640-2644.

Noda, Y., T. Kneyuki, K. Igarashi, A. Mori and L. Packer, 2000. Antioxidant activity of nasunin, an anthocyanin in eggplant peels. Toxicology, 148(2-3): 119-123.

Rathke, G.W., O. Christen and W. Diepenbrock, 2005. Effects of nitrogen source and rate on productivity and quality of winter oilseed rape (*Brassica napus* L.) grown in different crop rotations. Field Crop. Res., 94(2-3): 103-113.

Razak, N.F., 2012. A comparative study on antioxidant properties of different varieties of eggplant (*Solanum melongena*). Unspecified Thesis, Faculty of Applied Sciences, Universiti Teknologi MARA, Malaysia.

Sakamura, S., S. Watanabe and Y. Obata, 1963. The structure of the major anthocyanin in eggplant. Agr. Biol. Chem. Tokyo, 27(9): 663-665.

Savvas, D. and F. Lenz, 1996. Influence of NaCl concentration in the nutrient solution on mineral composition of eggplants grown in sand culture. J. Appl. Bot., 70(3-4): 124-127.

Schieber, A., P. Keller and R. Carle, 2001. Determination of phenolic acids and flavonoids of apple and pear by high-performance liquid chromatography. J. Chromatogr. A, 910(2): 265-273.

Shahidi, F., A. Chandrasekara and Y. Zhong, 2011. Bioactive Phytochemicals in Vegetables. In: Singha, N.K. (Ed.), Handbook of Vegetables and Vegetable Processing. John Wiley and Sons Publishing Ltd., Ames, IA, pp: 125-158.

Shi, J., H. Nawaz, J. Pohorly, G. Mittal, Y. Kakuda and Y. Jiang, 2005. Extraction of polyphenolics from plant material for functional foods-engineering and technology. Food Rev. Int., 21(1): 139-166.

Singh, H.P., S. Mittal, S. Kaur, D.R. Batish and R.K. Kohli, 2009. Chemical composition and antioxidant activity of essential oil from residues of *Artemisia scoparia*. Food Chem., 114: 642-645.

Singleton, V.L. and J.A. Rossi, 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Am. J. Enol. Viticult., 16(3): 144-158.

Wolever, T.M., 1990. Relationship between dietary fiber content and composition in foods and the glycemic index. Am. J. Clin. Nutr., 51(1): 72-75.

Xu, B.J. and S.K. Chang, 2007. A comparative study on phenolic profiles and antioxidant activities of legumes as affected by extraction solvents. J. Food Sci., 72(2): S159-S166.

Zhishen, J., T. Mengcheng and W. Jianming, 1999. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chem., 64(4): 555-559.