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Dietary fiber and total phenolic content of selected raw and cooked beans and its combinations

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Abstract

Beans are distinctive among a diverse and broad class of legumes. Certain health products claimed their products are high in dietary fibers and total phenolic content (TPC) because they applied bean combinations. This study aimed to determine the dietary fibers and TPC of raw and cooked beans and its combinations. Individual beans studied were kidney bean, mung bean and chickpea. Bean combinations were done by mixing each of the homogenized beans flour in the ratio of 1:1 (w/w) and 1:1:1 (w/w/w). Dietary fibers were determined using enzymatic-gravimetrical method whereas TPC was determined spectrophotometrically. Results showed the insoluble dietary fiber (IDF), soluble dietary fiber (SDF), total dietary fiber (TDF) and TPC for individual raw beans varied from 20.52 to 26.61 g/100 g, 1.20 to 2.45 g/100 g, 22.08 to 27.81 g/100 g and 0.48 to 1.04 mg GAE/g, respectively. For raw bean combinations, the IDF, SDF, TDF and TPC varied from 20.74 to 23.96 g/100 g, 2.3 to 2.50 g/100 g, 23.05 to 26.46 g/100 g and 0.80 to 0.85 mg GAE/g, respectively. No significant different ($p > 0.05$) in IDF and SDF for raw bean combinations and individual raw beans. Meanwhile, certain raw bean combinations contained significant higher ($p < 0.05$) TDF and TPC than individual raw beans. The IDF, SDF, TDF and TPC for individual cooked beans varied from 14.49 to 26.30 g/100 g, 1.40 to 2.02 g/100 g, 15.88 to 28.31 g/100 g and 0.57 to 1.20 mg GAE/g, respectively. For cooked bean combinations, the IDF, SDF, TDF and TPC varied from 15.73 to 23.03 g/100 g, 1.73 to 2.36 g/100 g, 17.46 to 24.95 g/100 g and 0.61 to 1.08 mg GAE/g, respectively. After cooking, the IDF, SDF, TDF and TPC of certain beans combinations were significantly higher ($p < 0.05$) than individual beans. This study supports the proposal that bean combinations can possibly be used as a method to increase the amount of dietary fibers and TPC.

Introduction

Dietary fibers are the edible portion of plants that is resistant to enzymatic digestion and absorption by the intestinal tract. Generally, dietary fibers can be categorized according to its digestibility in the small intestine into two basic groups, namely, soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). SDF dissolves in water and turns to gel during digestion. The gel forming characteristic allows the food to be slowed down while digestion and this indirectly contributes many health benefits such as reducing postprandial blood glucose, serum cholesterol and insulin levels (Jenkins *et al*., 2000). Meanwhile, IDF are unable to be digested and are poorly metabolized in the small intestine (Englyst *et al*., 2007). IDF have passive water-holding characteristics that can reduce the risk of constipation, diverticular disease and hemorrhoids (Anderson *et al*., 2009).

Phenolic compounds are a large group of phytochemicals found in the plant kingdom that act as natural antioxidant in prevention of several diseases such as atherosclerosis, diabetes mellitus, cardiovascular disease and cancer. The phenolic compounds can range from simple, low molecular-weight, single aromatic-ringed compounds to large and complex tannins and derived polyphenols (Crozier *et al*., 2009).

Legumes are among the earliest food crops that have been cultivated through the world. Beans are distinctive among a diverse and broad class of legumes (Uebersax, 2006). It has contributed as an important food category for humans for thousands of years and is typically incorporated in various forms

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of most traditional diets around the world. Beans are considered as nutrient-rich foods as it high in dietary fibers, protein, antioxidants, zinc, magnesium, folate, iron and omega-3 fatty acids (Darmadi-Blackberry *et al*., 2004; Mitchell *et al.*, 2009). Besides, the low glycemic index characteristic of beans are especially useful in mixed-meal settings, in which beans combined with a high glycemic index food such as white rice was able to produce a glycemic response that is intermediate between the high and low glycemic index foods (Winham *et al*., 2007).

Recently, researchers have focused public's attention on the dietary fibers and total phenolic content (TPC) of foods as there has been some evidence that diet low in dietary fibers and TPC are linked with several diseases development. People rarely eat raw beans as it contains anti-nutritional factors that can adversely affect enzyme activity, digestibility, nutrition and health. Generally, food processing can affect the dietary fibers and phenolic contents of beans (Guillon and Champ, 2000) and cooking is one of the common ways that people use in processing the beans.

Previous studies have demonstrated that high level of legumes intake has health-protective effects and disease-reversal benefits. Certain health products also are claiming their products are high in dietary fibers and TPC because they applied bean combinations. However, there are no published data to support these claims. The purpose of this study was to determine the dietary fibers and TPC of selected raw and cooked beans and its combinations.

Materials and methods

Samples

Chickpea (*Cicer arietinum* L), kidney bean (*Phaseolus vulgaris* L) and mung bean (*Vigna radiata* L. R. Wilczek) used in the present study were purchased from hypermarkets in Selangor. The beans in good condition (without broken, molded, mechanically damaged and wrinkled) were homogenized to a particle size less than 0.5 mm using an electrical blender (Panasonic, Malaysia). Then, the beans flour was sieved and stored at 4ºC in air tight containers until analyzed.

Cooking

Beans in good condition were initially washed with tap water prior cooking with an automatic rice cooker (Panasonic SR-E18A, Malaysia). Cooking time was defined according to the method of Williams *et al*. (1983), in which the beans were cooked until soft as determined by pressure felt between the fingers. The ratio of beans to cooking water was set according to Jood *et al.* (1998), which was 1: 3 (w/v). After 30 minutes, a few beans were taken out and pressed between fingers to test the degree of softness. When the beans were not soft, the process was continued for another 10 minutes or until the beans were soft. At the end of cooking, the water was drained and the cooked beans were freeze-dried and homogenized to a particle size less than 0.5 mm using an electrical blender (Panasonic, Malaysia). Then, the beans flour was sieved and stored at 4ºC in air tight containers until analyzed.

Preparation of combination beans flour

Combination of beans flour were done by mixing each of the homogenized beans flour in the ratio of 1:1 (w/w, for combination of two types of beans) and 1:1:1 (w/w/w, for combination of three types of beans).

Preparation of organic extracts

Extraction was done based on the method of Huang and Yen (2002) with a slight modification. About 1 g of the ground sample was mixed with 15 ml 80% (v/v) aqueous methanol and incubated at room temperature with continuous stirring for 2 hours by using an orbital shaker (Heidolph Unimax 1010 DT, Germany) at 150 rpm before centrifuged at 4000 rpm for 10 minutes using centrifuge model Rotofix 32 A (Hettich, Germany). The supernatant obtained was assayed for TPC.

Dietary fibers determination

AOAC Official method 991.43 (1995) with slight modifications was used for dietary fibers determination. This method is an enzymatic-gravimetric method that utilized three different enzymes (heat-stable a-amylase, protease and amyloglucosidase) under different incubation conditions in order to remove starch and protein components. For IDF determination, the enzyme digestate was filtered, and residue was washed with warm water, dried and weighed whereas for SDF determination, combined filtrate and washes were precipitated with alcohol, filtered, dried and weighed. Lastly, the values obtained in IDF and SDF were sum up to become TDF.

TPC determination

TPC determination done based on the method of Marathe *et al.* (2011) with slight modifications. This is an oxidation-reduction colorimetric method, whereby exactly 600 µl of extracted samples was pipette into a test tube. Next, 300 µl of 1 N Folin-

Ciocalteu reagent and 600 µl of 2.0% sodium carbonate solution were added and the mixture was allowed to stand in a dark for 30 minutes. Then, the absorbance of the mixture was measured against blank solution at the wavelength 750 nm using spectrophotometer (Shimadzu, Australia).

Statistical analysis

All statistical analyses were conducted using Statistical Package for Social Science (SPSS) version 21. One-way analysis of variance (ANOVA) accompanied with Turkey's post hoc was used to determine the significant differences between TDF, SDF and IDF of raw and cooked dry beans and its combination. Independent T-test was used to compare the changes in dietary fibers and TPC after being cooked. The level of significant was set at $p < 0.05$ for all tests.

Results and Discussion

IDF, SDF, TDF and IDF/ SDF ratio of raw beans and its combinations

IDF, SDF, TDF and IDF/ SDF ratio of raw beans and its combinations are presented in Table 1. For individual raw beans, the IDF, SDF and TDF varied from 20.52 to 26.61 g/100 g, 1.20 to 2.45 g/100 g and 22.08 to 27.81 g/100 g, respectively. Mung bean had the greatest amount of IDF and TDF whereas chickpea had the lowest. According to Wang *et al.* (2003), beans with small seed size will had a higher TDF content than those with large seed size because small size seeds having a greater surface to volume ratio than large size seeds, exhibited a greater proportion of seed coat to cotyledon. Hence, mung bean with small seed size had thicker seed coat and higher fiber content than did large size seeds such as kidney bean and chickpea. SDF content of kidney bean was the highest whereas mung bean was the lowest when compared among individual beans studied. Current findings contrary with Mallillin *et al.* (2008) who observed the IDF content of kidney bean was highest whereas the SDF content of kidney bean was lowest, as compared with mung bean and chickpea. The different may due to the environmental planting conditions, environmental interaction, agronomic practices and plant variety of the beans (Martin-Cabrejas *et al*., 2006; Wang *et al.*, 2008).

For raw bean combinations, the IDF, SDF and TDF ranged from 20.74 to 23.96 g/100 g, 2.3 to 2.50 g/100 g and 23.05 to 26.46 g/100 g, respectively. Combination of kidney bean & mung bean had the highest amount of IDF, SDF and TDF whereas combination of kidney bean & chickpea had the lowest. Multiple comparison of results showed that combinations of raw beans do not enhance the amount of IDF and SDF than its individual form. Conversely, certain beans in combination were able significantly increased its TDF value. The TDF content in chickpea was significantly lower ($p < 0.05$) than combination of mung bean and chickpea and combination of kidney bean, mung bean & chickpea.

IDF/SDF ratio is an important variant related to functional, sensorial and structural properties of food products containing legumes fibers (Tiwari *et al*., 2011). The higher the IDF/SDF ratio indicates that the beans contain higher proportion of insoluble fiber than soluble fiber and the beans are mainly composed of cellulose, hemicellulose and lignin. When compared the IDF/SDF ratio of individual raw beans and combinations of raw beans in Table 1, it was observed that IDF/SDF ratio was highest in mung bean (22.17) and lowest in combination of kidney bean and chickpea (8.97). This indicated combination of kidney bean & chickpea can yield a higher amount of pectins, mucilages and gums. Pectins, mucilages and gums are the major constituents of SDF.

IDF, SDF, TDF and IDF/ SDF ratio of cooked beans and its combinations

IDF, SDF, TDF and IDF/ SDF ratio of cooked beans and its combinations are presented in Table 1. The IDF, SDF and TDF for individual cooked beans varied from 14.49 to 26.30 g/100 g, 1.40 to 2.02 g/100 g and 15.88 to 28.31 g/100 g, respectively. Kidney bean had the highest amount of IDF and TDF whereas mung bean had the highest amount of SDF. Meanwhile, chickpea had the lowest amount of IDF, SDF and TDF. The different may due to the environmental planting conditions, environmental interaction, agronomic practices and plant variety in beans (Martin-Cabrejas *et al*., 2006; Wang *et al*., 2008). Moreover, the results indicated that cooking can affect the dietary fibers content of beans.

For cooked bean combinations, the IDF, SDF and TDF varied from 15.73 to 23.03 g/100 g, 1.73 to 2.36 g/100 g and 17.46 to 24.95 g/100 g, respectively. Combination of kidney bean, mung bean and chickpea had the highest amount of IDF and TDF whereas combination of kidney bean and mung bean had the highest amount of SDF. Meanwhile, combination of mung bean and chickpea had the lowest amount of IDF, SDF and TDF. Multiple comparison of results demonstrated that IDF, SDF and TDF value of certain cooked beans combinations were significantly higher than individual cooked beans. As compared with individual cooked beans, the IDF content in combination of kidney bean, mung

Table 1. Dietary fibers of raw and cooked beans and its combinations

Samples	IDF (g/100g)		SDF (g/100g)		TDF (g/100g)		IDF/SDF	
	Raw	Cooked	Raw	Cooked	Raw	Cooked	Raw	Cooked
Kidney bean	25.21 ± 0.15^{a}	26.30 ± 0.87^{a}	2.45 ± 0.66^{ab}	2.01 ± 0.25^{ab}	27.66 ± 0.81^{a}	28.31 ± 0.62^{a}	10.29	13.08
Mung bean	26.61 ± 0.22^{ab}	17.36 ± 0.61^{f} *	1.20 ± 0.05^{ab}	2.02 ± 0.21^{ab}	27.81 ± 0.17^{ab}	19.38 ± 0.82^{b}	22.17	8.61
Chickpea	20.52 ± 0.26^{c}	14.49 ± 0.67^{c} *	1.56 ± 0.41^{abc}	1.40 ± 0.01^{c}	22.08 ± 0.68^{c}	15.88 ± 0.63^{c} *	13.17	10.37
Kidney bean & Mung bean	23.96 ± 0.12^{ad}	21.80 ± 0.05^{d} *	2.50 ± 0.02^{acd}	2.36 ± 0.08^{abd}	26.46 ± 0.10^{abd}	24.15 ± 0.13^{d} *	9.60	9.25
Kidney bean & Chickpea	20.74 ± 0.74^{ce}	19.13 ± 0.40^{b}	2.31 ± 0.13^{abcde}	1.80 ± 0.11^{abcde} *	23.05 ± 0.87^{ce}	20.93 ± 0.29^{a}	8.97	10.62
Mung bean & Chickpea	22.22 ± 0.69^{cdef}	15.73 ± 0.27^{bc} *	2.42 ± 0.35^{abcdef}	1.73 ± 0.09^{abcef}	24.64 ± 0.35^{def}	17.46 ± 0.36^{bc} *	9.17	9.10
Kidney bean, Mung bean & Chickpea	23.48 ± 0.60^{adf}	23.03 ± 0.58^{d} *	2.42 ± 0.08^{abcdef}	1.92 ± 0.09^{abcdef}	25.90 ± 0.68^{abdf}	24.95 ± 0.49^{d}	9.70	12.01

Values are expressed as mean ± standard deviation. Means in same column with different letters (a-f) are significantly different at $p < 0.05$ based on one way ANOVA, Tukey's post-hoc. The symbol (*) indicates significant different at $p < 0.05$ based on independent T-test.

bean and chickpea were significantly higher ($p < 0.05$) than all individual beans studied. Besides, the IDF and TDF content in combination of kidney bean and mung bean were significantly higher ($p < 0.05$) than mung bean and chickpea. Also, it was observed the amount of SDF in combination of kidney bean and mung bean was significantly higher ($p < 0.05$) than chickpea.

When compared the IDF/SDF ratio of individual cooked beans and combinations of cooked beans in Table 1, it was noticed that IDF/SDF ratio was highest in kidney bean (13.08) and lowest in mung bean (8.61). The IDF/SDF ratio for combination of cooked bean was within the range of 9.10 to 12.01. This indicated that beans combination contained higher proportion of IDF than SDF and was mainly composed of cellulose, hemi cellulose and lignin. Cellulose, hemi cellulose and lignin are the major constituents of IDF.

Effect of cooking on dietary fibers

Current findings fairly agree with Mahadevamma and Tharanathan (2004), who reported that cooking reduced the SDF and IDF of beans. Our study demonstrated that cooking reduced the amount IDF, SDF and TDF for all the studied beans and its combinations except kidney bean and mung bean. All the studied beans and its combinations showed reduction in IDF and TDF after being cooked except kidney bean. The increment in IDF and TDF of kidney bean after cooking process were also observed by Wang *et al.* (2010). This may be due to protein–fiber complexes formed after possible chemical modification induced by the cooking of raw beans (Bressani, 1993).

On the other hands, mung bean was the only bean that showed increment of SDF after being cooked. This result agrees with finding of Mahadevamma and Tharanathan (2004). The increase in SDF of mung bean may be due to the formation of resistant starch after cooking (Mongeau and Brassard, 1995)

TPC of raw beans and its combinations

Table 2 shows the amount of TPC in various raw beans and its combinations. The TPC of individual raw beans ranged from 0.48 to 1.04 mg GAE/g, being highest in kidney bean and lowest in mung bean. This was fairly agrees with Marathe *et al.* (2011), who reported the phenolic content of beans varied in the range of 0.33 to 6.38 mg GAE/g. The TPC in combinations of raw beans ranged from 0.80 mg GAE/g to 0.85 mg GAE/g. Combination of mung bean & chickpea was found to be the highest whereas combination of kidney bean & mung bean was found to be the lowest. When compared the TPC in raw beans and combinations of raw beans, it was observed that all types of beans in combinations studied were significantly higher ($p < 0.05$) than mung bean.

TPC of cooked beans and its combinations

The amount of TPC in various cooked beans and its combinations are presented in Table 2. The TPC of individual cooked beans ranged from 0.57 to 1.20 mg GAE/g, being highest in kidney bean and lowest in

Table 2. TPC of raw and cooked beans and its combinations

Samples	TPC (mg GAE/g)		
	Raw	Cooked	
Kidney bean	1.04 ± 0.02^{a}	1.20 ± 0.04^{a}	*
Mung bean	0.48 ± 0.01^{b}	0.57 ± 0.07^{b}	
Chickpea	0.88 ± 0.05^{c}	0.71 ± 0.03^{bc}	*
Kidney bean & Mung bean	0.80 ± 0.03^{cd}	1.08 ± 0.01^{ad}	*
Kidney bean & Chickpea	0.84 ± 0.01^{cde}	0.61 ± 0.09^{bc}	*
Mung bean & Chickpea	0.85 ± 0.02^{cdef}	0.76 ± 0.02^{c}	*
Kidney bean, Mung bean & Chickpea	0.84 ± 0.03^{cdef}	0.95 ± 0.06^{d}	

Values are expressed as mean ±standard deviation. Means in same column with different letters (a-f) are significantly different at $p < 0.05$ based on one way ANOVA, Tukey's post-hoc. The symbol (*) indicates significantly different at $p < 0.05$ based on independent T-test.

mung bean. These results contradicted with findings of Gujral *et al.* (2013), who reported the TPC for chickpea was the lowest whereas the TPC for kidney bean was the highest after being cooked. The possible reasons contributed to the variation in phenolic content among the beans are the environmental planting conditions, genetic factors and degree of maturity of beans (Marathe *et al.*, 2011).

The TPC in combinations of cooked beans ranged from 0.61 to 1.08 mg GAE/g. Combination of kidney bean and mung bean was found to be the highest whereas combination of kidney bean and chickpea was found to be the lowest. When compared the TPC in individual cooked beans and combinations of cooked beans, it was observed that the TPC in combination of kidney bean, mung bean and chickpea and combination of kidney bean & mung bean were significantly higher ($p < 0.05$) than chickpea and mung bean. In addition, the TPC in combination of mung bean and chickpea was significantly higher ($p < 0.05$) than mung bean.

Effect of cooking on TPC

The findings of this study was supported by a published data of Turkmen *et al.* (2005), who reported cooking caused loss or increment of phenolics in vegetables and legumes. After cooking, as compared with raw form, the TPC in chickpea, combination of kidney bean, chickpea and combination of mung bean and chickpea were significantly reduced ($p < 0.05$). The reduction of TPC could be due to phenolics breakdown during cooking (Crozier *et al*., 1997).

On the other hand, cooking was found to give rise to phenolic content in kidney bean, mung bean, combination of kidney bean, mung bean and combination of kidney bean, mung bean and chickpea. The TPC in kidney bean and mung bean were significantly increased ($p < 0.05$) to various extents. The increment of TPC could be due to heat treatment that increased the level of free flavonols (Stewart *et al*., 2000).

Data on combinations of beans has not been investigated in previous studies, hence, comparison was only for individual beans. The findings on TPC of kidney bean is in agreement with Gujral *et al.* (2013), who observed the TPC in kidney beans decreased after being cooked. Moreover, the findings on TPC of chickpea is supported by published data of Xu and Chang (2008) and Gujral *et al*. (2013), who revealed the TPC of chickpea reduced after being cooked. Although the TPC in mung bean was not significantly increased ($p > 0.05$) after being cooked, but the findings obtained were inconsistent with Xu and Chang (2008), who reported the TPC of mung bean decreased after being cooked.

Conclusion

Combinations of raw beans do not enhance the IDF and SDF levels than its individual form. After cooking, the IDF and SDF of certain cooked beans combinations were significantly higher than individual cooked beans. Certain bean combinations yielded greater amount of TDF and TPC than individual beans either in raw or cooked form. This study supports the proposal that bean combinations can possibility be used as method to increase the amount of dietary fibers and TPC.

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