

PRODUCTION AND STORAGE STABILITY OF ANTIOXIDANT FIBER FROM PIGEON PEA (*CAJANUS CAJAN*) POD

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ABSTRACT

Pigeon pea (*Cajanus cajan*) pods were considered byproducts obtained from food industry which was raw material for the production of antioxidant fiber powder in this investigation. The effects of pretreatment (washing and blanching) and drying temperatures (60, 70, and 80°C) on total crude fiber contents, total phenolic concentration and antioxidant activity by the method of DPPH radical scavenging activity and FRAP were evaluated. The results showed that blanched (60°C) samples had the shortest drying times of 9.03 h. However, blanching significantly ($p \leq 0.05$) reduced antioxidant capacity of dried pigeon pea pod powders when compared to washing with tap water and fresh sample. Higher drying temperature tended to decrease fiber contents and antioxidant activity of dried powder. The pigeon pea pod powders were stored in ziplock bags or vacuum packaging at room temperature for 8 weeks. The moisture content of the powder kept in both packaging increased over time, which correlated with the water activity during 8 weeks of storage. In addition, storage times caused a decline in the levels of total phenolic concentration, DPPH, and FRAP values. The amount of total phenolic concentration, DPPH and FRAP of vacuum-packed samples were significantly higher than those stored in ziplock bags during storage. It could be concluded that washing with tap water and drying temperature of 60°C was the most suitable condition for the process of fiber powder with antioxidant activity preparation from pigeon pea pod. Moreover, vacuum packaging method was sufficient to maintain the antioxidant capacity of the sample for 8 weeks.

Keywords: Pigeon pea, pod, crude fiber, antioxidant, powder, storage

INTRODUCTION

Dietary fiber was portion of food that was not digested by human digestive enzymes (Chantaro *et al.*, 2008). A higher intake of dietary fiber was associated with health benefits with a reduced risk of the diseases such as hypertension, diabetes, obesity, coronary heart disease, cancer, and certain gastrointestinal disorders (Anderson *et al.*, 2009). In part, some of these benefits had been attributed to the consumption of foods rich in both of dietary fiber and antioxidant compounds like fruits and vegetables, which could reduce oxidative stress caused by free radicals (Gokmen *et al.*, 2009). Antioxidant and biological properties of bioactive phenolic compounds from plant foods depended on their ability to react with free radicals and was also associated with antioxidant activity (Corral-Aguayo *et al.*, 2008). Hence, the monitoring of the antioxidant capacity had been utilized for the determination of food quality in relation to health (Gokmen *et al.*, 2009).

Both the characteristics of the raw materials and the processing steps affected the compositions and physicochemical properties of dietary fibers (Chau *et al.*, 2004). For processing steps, the reaction of enzymes were inactivated by blanching before drying process. Consequences of blanching with water resulted in some leaching of water-soluble food constituents such as vitamins, minerals, sugars, and starch. Moreover, air drying at a high temperature promoted a decrease of some soluble dietary fiber components and thus reducing the hydration properties of the fiber (Chantaro *et al.*, 2008).

The pod of pigeon pea was a commonly generated waste from both households and food-processing industries. Gan *et al.* (2016) reviewed that the antioxidant activity and total phenolic concentration of most pigmented edible beans was higher than non-pigmented ones. Therefore, it could be expected that pigmented beans pod with a black, red and green color might be rich in antioxidant polyphenols. The feasibility study of using the pod of pigeon pea, the waste from the frozen pigeon pea seed manufacturing industry, as a starting raw material was conducted to produce high antioxidant fiber powder in this work. The effects of

blanching and drying temperature on antioxidant activities and quality of fiber powder were investigated. In addition, the comparison of two storage methods, which included ziplock bags and vacuum packaging were evaluated for the stability of total phenolic concentration and antioxidant activity of the pod dried powder. The results obtained could be used as basic information for industrial production of antioxidant fiber powder, which was beneficial in terms of the reduction in waste accumulation, value addition of waste, as well as introducing a new functional ingredients in a healthy and safe diet.

MATERIAL AND METHODS

Material

Pigeon pea pods were obtained from Lanna Agro Industry Co., Ltd. (Chiang Mai, Thailand). The pods were washed gently with tap water and then cut into 1.0 × 1.0 cm. The samples were then stored at 4°C until use.

Preparation of antioxidant fiber powder

A 3×3 factorial in a completely randomized design (CRD) was applied to investigate the effect of two variables, namely raw material preparation and drying temperature. Factor levels for raw material preparation consisted of fresh pods, pods washed with tap water at 1:5 (w/v) ratio and pods blanched in hot water at 60°C within 1 min with solid-to-solvent ratio of 1:15 (w/v). Each treatment was spreaded on aluminum tray and subjected to hot air drying (Memmert, Model 400, Oxford, United Kingdom) at 60, 70, and 80°C. The drying process was performed until reaching the final moisture content of less than 10 g/100 dry weights (Chantaro *et al.*, 2008). All dried samples were then ground to a powder using a kitchen mill (Otto, OT-122G, Thailand) at 25,000 rpm and sieved using 500 µm standard meshes to ensure homogeneity of particle size and vacuum-packed in the plastic bag until analysis. All treatments were

analyzed for crude fiber contents, total phenolic concentration, 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity and ferric reducing antioxidant power (FRAP). The experiment was performed in triplicates.

Sample extraction

The extraction of antioxidant compound from each sample (5 g) was performed with 50 ml of 80% (v/v) ethanol solution in an orbital shaker at ambient temperature (27 ± 2°C) for 2 h at a shaking speed of 100 rpm. The mixture were separated by centrifugation at 1400 × g for 20 min and the supernatant was collected to use for further determination of total phenolic concentration, DPPH radical scavenging activity and FRAP.

Storage stability of dried powders

The dried powders obtained from the best preparation method (blanching and drying process) were stored in ziplock bags or vacuum-packed in polyethylene bag at ambient temperature (27 ± 5°C). Sampling was conducted at 0, 2, 4, 6 and 8 weeks of the storage. The samples in both of ziplock bags and vacuum-packed bags were analyzed for water activity (a_w), moisture content, total phenolic concentration, DPPH radical scavenging activity and FRAP.

Determination of crude fiber contents

The method to determine crude fiber content consisted of acid and alkali digestion in accordance with the AOAC (2000). A crucible, which was washed and dried at 105°C for 1 h to prevent impurities, was added with 2 g of dried ground sample. This initial weight of crucible was recorded. The solution of 1.25% sulfuric acid at 150 ml was added to the sample and the mixture was boiled for 30 minutes with condenser to maintain the concentration of the acid. The precipitate was collected upon a filter and thoroughly washed with hot water until no longer acidic. Then, the sample was digested for 30 min with 150 ml alkali solution (1.25% sodium hydroxide). The residue was washed with hot water until washings were neutral. The porcelain crucibles together with final residue were dried at 105°C in an oven for 60 min, cooled in a desiccator and then weighed. The dried sample was placed in a crucible and ignited in the furnace at 550°C for 3 h, then cooled. The weight of the residue was recorded. The percent of crude fiber content was calculated using the following equation.

$$\text{Crude fiber (\%)} = \frac{(\text{Crucible with ash residue weight} - \text{empty crucible weight})}{\text{Sample weight}} \times 100$$

Determination of moisture content

3 g of pigeon pea pod powder were dried in hot air oven at 105°C for 4-5 h (AOAC, 2000). The moisture content was then calculated by the following equation.

$$\text{Moisture content (\%)} = \frac{(\text{Initial weight} - \text{Oven dry weight})}{\text{Sample weight}} \times 100$$

Determination of water activity (a_w)

Water activity of dried pod powder was determined by using a water activity meter (AquaLab, Washington, USA). The a_w was determined from triplicate 2 g ground samples held at 25±0.1°C until equilibrium reached.

Determination of total phenolic content

The content of the total phenolic compounds of each sample was determined by Folin-Ciocalteu assay (Yu et al., 2005). 200 µl of extracted sample was mixed with 800 µl of the Folin-Ciocalteu reagent and 3 ml of distilled water. After 5 min, 2 ml of 7.5% (w/v) sodium carbonate was added to the mixture and the volume was made up to 3 ml with distilled water. The reaction was kept in the dark for 2 h at ambient temperature. After centrifugation, the absorbance of different samples were measured at 765 nm by a UV-Vis spectrophotometer (Genesys, G-10UVS, USA). The total phenolic concentration was calculated as mg gallic acid equivalent per gram of dry weight (mg GAE/g) on the basis of a standard curve of gallic acid (50-250 µg/ml, y = 0.0021x - 0.0154 (R² = 0.9991)). All determinations were carried out in triplicate.

Determination of DPPH radical scavenging activity

The DPPH free radical scavenging activity of the extract from dried pod powder, based on the scavenging of the stable 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical was determined (Brand-Williams et al., 1995). This assay measured the ability of compounds presented in a sample to act as the complexing agent of the free radical DPPH and monitored through the decrease in absorbance. Briefly, the 3 ml of 0.6 mM DPPH solution was added in 0.1 ml of ethanolic extract. After 30 min incubation in the dark and at room temperature, the absorbance was measured at 517 nm using a UV-Vis spectrophotometer. A calibration curve was

constructed with Trolox solution (0-600 µM). Results were expressed as Trolox (µM) equivalents per gram dried pigeon pea pod powder.

Determination of FRAP

A modified method of Benzie and Strain (1996) was adopted for the FRAP assay. Briefly, the FRAP reagent contained 25 ml acetate buffer (300 mM acetate buffer, pH 3.6), 2.5 ml of 10 mM TPTZ (2, 4, 6-tripyridyl-s-triazine) solution, and 2.5 ml of 20 mM FeCl₃ solution. The mixture of dried pod powder extracts (150 µl) and 1.9 ml FRAP solution was allowed to react for 30 min in the dark condition. Readings of the coloured product (ferrous tripyridyltriazine complex) were taken at 593 nm using a UV-Vis spectrophotometer. A calibration curve was constructed using Trolox (0 - 600 µM) and results were expressed as Trolox equivalents per gram dried pigeon pea pod powder.

Statistical analysis

Assays were performed in triplicate and results were shown as mean ± standard deviation. The results obtained were statistically analyzed using SPSS for Windows 22.0 (SPSS Inc., Chicago, IL, USA) and the analysis of variance using Duncan's Multiple Range Test (DMRT) at p≤0.05

RESULTS AND DISCUSSION

Preparation of antioxidant fiber powder

Both blanched and unblanched pigeon pea pod were dried in a hot air oven at the temperature between 60 and 80°C to the moisture content of less than 10 g/100 dry weights. The drying time of 20 to 72 h was required for drying the sample to the desired moisture content of 9.03 to 9.98 g/100 g dry weight. A shorter drying time can be observed at higher drying temperature (Table 1). These probably due to drying at higher temperatures increased the rates of mass transfer and moisture diffusivity (Leeratanarak et al., 2006). The drying time was similar to that of carrot peels, which the moisture content of less than 9.9 g/100 g dry weight was obtained from drying at the temperature of 60, 70 and 80°C at 12.5, 10.0, and 7.5 h, respectively (Chantaro et al., 2008). In addition, it was also observed that the blanched samples took shorter drying time compared to the unblanched one as shown in Table 1. Drying of blanched sample at the temperatures of 80°C took the shortest time of 20 h to reach the desired moisture contents of 9.03 g/100 g dry weight. This result was also found in pitaya (*Hylocereus undatus*) peel sample that the fastest drying process (10 h) was drying of blanched (hot water at 95 ± 2°C for 1 min) sample at 80°C. Blanching caused damage to cell wall and moisture could be more easily released from plant tissue during drying (Nilnakara et al., 2009).

Table 1 Drying time of pigeon pea pod with final moisture content less than 10 g/100 g dry weight.

| Pigeon pea peels | Drying temperature (°C) | Drying time (h) | Equilibrium moisture content (g/100 g dry weight) |
|-----------------------|-------------------------|-----------------|---|
| Fresh | 60 | 72 | 9.98 |
| | 70 | 54 | 9.88 |
| | 80 | 24 | 9.16 |
| Washed with tap water | 60 | 72 | 9.75 |
| | 70 | 52 | 9.53 |
| | 80 | 22 | 9.11 |
| Blanched | 60 | 60 | 9.67 |
| | 70 | 45 | 9.40 |
| | 80 | 20 | 9.03 |

The pigeon pea pod powder with the highest crude fiber content of 31.50 ± 0.11 g/100 g dry weight was obtained from fresh sample dried at temperature of 60°C. However, the value was not significantly different from washed sample with the corresponding crude fiber contents of 31.41 ± 0.26 g/100 g dry weight as indicated in Figure 1. Moreover, the crude fiber contents from unblanched sample were higher than blanched sample, which was in the range of 30.85-31.50 and 29.38-30.55 g/100 g dry weight, respectively. This was because blanching process was responsible for the soluble dietary fiber components included pectin to be removed from fiber, especially hot water washing (Chantaro et al., 2008; Nilnakara et al., 2009).

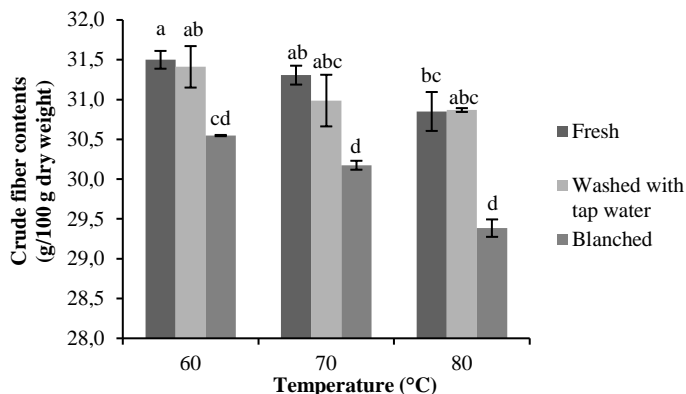


Figure 1 Crude fiber contents of pigeon pea pod powders (g/100 g dry weight) at various pretreatment and drying conditions.

High crude fiber content could be observed in the sample obtained from drying at lower temperature. This may due to degradation of fiber components, e.g. pectin, cellulose or hemicellulose, at high drying temperature. The result was consistent with that of **Sengkhampan et al. (2013)** who reported that the increase of drying temperature (60, 70, and 80°C) caused the decrease in dietary fiber

content (30.15 ± 0.74, 29.58 ± 0.28, and 28.00 ± 0.71, respectively) of blanched pitaya peel powder. However, the temperature range used in this study had been reported that it had no effect on the compositions of dietary fiber powder in green bell pepper (**Faustino et al., 2007**).

Total phenolic concentration in dried pigeon pea pod powders from different processes are shown in Table 2. The highest concentration of total phenolics was found in powder from fresh sample dried at 60°C (2.48 ± 0.09 mg/g dry weight), which was not significantly different ($p>0.05$) from washed sample dried at the same temperature (2.42 ± 0.11 mg/g dry weight). However, total phenolic content was significantly decreased ($p<0.05$) in blanched sample (71.55 ± 1.75%) when compared to fresh sample. **Chantaro et al. (2008)** had also reported similar result that approximately 24.69% of phenolic compounds in carrot peels were lost after blanching. The higher loss of total phenolic concentration observed in the present work might be from the higher temperature (60°C) of water for blanching. According to **Al-Farsi and Lee (2008)** who reported that increasing water temperature from 25 to 60°C resulted in higher phenolic content extraction (6.51 and 8.80 g/100 g, respectively) from date seeds. Extraction at high temperature increased both solute solubility and the diffusion coefficient, soften plant tissue, and liberated phenolics bounded to protein and polysaccharides into the solvent (**Shi et al., 2003**).

Table 2 Effect of pretreatment and drying temperature on total phenolic content, DPPH radical scavenging activity and FRAP value of dried powders produced from pigeon pea pod.

| Pretreatment | Drying temperature (°C) | Total phenolic content (mg GAE/g dry weight) | DPPH (µmol Trolox/g dry weight) | FRAP (µmol Trolox/g dry weight) |
|--------------|-------------------------|--|---------------------------------|---------------------------------|
| Fresh | 60 | 2.48 ± 0.09 ^a | 45.77 ± 0.15 ^a | 25.64 ± 0.02 ^{bcd} |
| | 70 | 2.17 ± 0.03 ^a | 43.62 ± 0.09 ^{bc} | 24.26 ± 0.21 ^{cd} |
| | 80 | 1.76 ± 0.05 ^b | 42.98 ± 0.44 ^{bc} | 24.26 ± 0.59 ^{cd} |
| Washed | 60 | 2.42 ± 0.11 ^a | 45.57 ± 0.07 ^a | 28.64 ± 0.03 ^a |
| | 70 | 1.50 ± 0.04 ^b | 42.36 ± 0.12 ^{cd} | 27.15 ± 0.31 ^{ab} |
| | 80 | 1.48 ± 0.04 ^b | 42.89 ± 0.51 ^{bc} | 26.18 ± 0.67 ^{bc} |
| Blanched | 60 | 0.62 ± 0.03 ^c | 43.96 ± 0.04 ^b | 25.82 ± 0.05 ^{bcd} |
| | 70 | 0.64 ± 0.01 ^c | 42.46 ± 0.17 ^{cd} | 26.28 ± 0.69 ^{bc} |
| | 80 | 0.54 ± 0.06 ^c | 41.42 ± 0.14 ^d | 23.72 ± 0.42 ^d |

The number with different alphabet (a - d) in the same column indicated significant difference at $p<0.05$.

Higher loss of total phenolic content was observed at higher drying temperatures. The lowest concentration of phenolic content (0.54 ± 0.06 mg/g dry weight) was found in blanched sample dried at 80°C. **Reis et al. (2013)** also reported that total phenolic content of fresh pepper (9.75 mg/g dry weight) was significantly higher ($p<0.05$) than all dried samples. Moreover, the higher drying temperature (45, 55, and 65°C) influenced a decrease in the concentration of total phenolic (1.48, 1.45, and 1.42 mg/g dry weight, respectively). The main factor responsible for the loss of total phenolic content during drying was thermal degradation (**Wolfe and Liu, 2003**). Shorter drying time may retain phenolic compounds during drying. Hence, a balance between drying temperature and time could reduce costs of processing and retain amounts of total phenolic concentration (**Sun et al., 2002**).

The radical scavenging activity of fiber-rich powder from pigeon pea pod was analyzed by DPPH and FRAP assays which widely used for determination of antioxidant activity of plant extracts (**Sengkhampan et al., 2013**). The antioxidant activity of samples is shown in Table 2. For DPPH assay, the highest radical scavenging activity of 45.77 ± 0.15 µmol Trolox/g dry weight was found in the powder obtained from fresh sample dried at 60°C. However, there was no significant differences from the powders obtained from washed sample dried at the same temperature (45.57 ± 0.07 µmol Trolox/g dry weight). The DPPH radical scavenging activity of powder from blanched sample was less than unblanched samples, except for sample dried at 70°C. This was probably due to leaching of phenolic compounds. In addition, the higher drying temperature at 70 and 80°C decreased the radical scavenging capacity of sample to the range of 41.42 - 43.62 µmol Trolox/g dry weight. Trend of DPPH radical scavenging activity was associated with that of total phenolic content, which tended to be lost at high drying temperature. **Reis et al. (2013)** stated that the loss of antioxidant activity can be retarded at lower temperatures. Therefore, the DPPH radical scavenging activity of pigeon pea pod powder could be linked to the polyphenols (**Cai et al., 2003**).

The quantitative evaluation of FRAP for the pigeon pea pod powder showed the decreasing trend of FRAP value with higher drying temperatures. The highest FRAP value of 28.64 ± 0.03 µmol Trolox/g dry weight was found in powder obtained from washed sample dried at 60°C, which was not significant differences ($p>0.05$) from the dried pod powders from drying temperature of 70°C with the same pretreatment (27.15 ± 0.31 µmol Trolox/g dry weight). Similar results had been reported by **Wojdylo et al. (2007)** for dried apple. The drying processes of apple flesh with higher temperatures (50, 60, and 70°C)

caused the loss of FRAP value (26.70±0.03, 28.57±0.00, and 25.65±0.06 µmol Trolox/100 g dry weight, respectively). However, the trend of antioxidant activity by FRAP assay observed in this result was not associated with the total phenolic concentration. The increase of antioxidant activity with decreased total phenolic content could be due to increased antioxidant power of intermediate oxidation products of phenolic compounds, increase in reducing sugars from degradation of dietary fiber components and formation of Maillard reaction products (**Madraa et al., 2009**).

Although, some antioxidative compounds were lost during washing and drying, the total phenolic compound and antioxidant activity were not significantly different for the powder produced from fresh and washed pigeon pea pods. Therefore, washing with tap water prior to drying process at 60°C was preferable, which provided better chemical and functional properties of the final product. Moreover, washing procedure was also an important process for removal of contaminants and preparation for further processing in a food manufacturing plant in order to produce high quality food products.

Effects of different packaging methods on quality of pigeon pea pods powder during storage

Dried powder of pigeon pea pods was assessed during storage in two different packing methods, including ziplock bag and vacuum packaging. The result showed that a_w and moisture content of both methods slightly increases during 8 weeks of storage. The moisture content of the powder slightly increased to 12.84 ± 0.05 and 11.15 ± 0.06% after 8 weeks at room temperature from an initial value of 9.09 ± 0.02 and 9.10 ± 0.03% in ziplock and vacuum-packed samples, respectively. The increase was found to be significant after 4 weeks for ziplock bag and 6 weeks for vacuum packaging ($p<0.05$). **Selvamuthukumaran and Khanum (2014)** also reported similar findings of increase in moisture content of the sea buckthorn fruit juice powder from 4.01% to 5.01 and 4.71% after 8 months of storage at room temperature in air and vacuum-packed sample, respectively. The a_w from vacuum-packed sample was less than 0.6 throughout the whole storage period which was considered as microbiologically safe and was classified as a dehydrated food (**Kowalski and Szadzińska 2014**).

Quantitative evaluation of total phenolic concentration, DPPH and FRAP antioxidant activity in ziplock and vacuum-packed samples decreased during storage (Table 3). It could be seen that the concentration of total phenolic (3.39 ± 0.02 mg GAE/g dry weight) and DPPH radical scavenging activity (57.87 ± 0.23

µmol Trolox/g dry weight) and FRAP (12.05 ± 0.11 µmol Trolox/g dry weight) in pigeon pea pods powders were significantly higher ($p \leq 0.05$) in vacuum-packed sample than that stored in the presence of air in ziplock bag after 8 weeks storage. Wang (2013) evaluated the impact of vacuum versus non-vacuum packaging on the change in antioxidant contents and antioxidant capacity during frozen storage of pawpaw pulp and indicated that total phenolic concentration, DPPH and FRAP values in pawpaw pulp were significantly affected by the presence of air during storage. The mean value of total phenolic concentration decreased by 39% in

vacuum-packed pawpaw pulp, which was lower than the samples in the presence of air (decreased by 71%) over 12 months of storage. The loss of phenolic compounds was pronounced in air-packed samples, while it was lower in vacuum-packed samples. The loss of phenolics in air-packed samples may be due to oxidation of the phenolic compounds in the presence of oxygen. Agbenorhevi and Marshall (2012) also observed similar results showing loss of total phenolic content in fruit smoothies during storage at 4°C for a period of 4 weeks.

Table 3 Effect of different packaging methods on quality of pigeon pea pods powder during 8 weeks storage.

| Storage (week) | Packaging | a_w | Moisture content (%) | Total phenolic content (mg GAE/g dry weight) | DPPH (µmol Trolox / g dry weight) | FRAP (µmol Trolox / g dry weight) |
|----------------|-----------|---------------------------|----------------------------|--|-----------------------------------|-----------------------------------|
| 0 | Ziplock | 0.52 ± 0.01 ^{cd} | 9.09 ± 0.02 ^e | 3.61 ± 0.03 ^{ab} | 69.91 ± 0.11 ^a | 17.12 ± 0.52 ^a |
| | Vacuum | 0.50 ± 0.01 ^d | 9.10 ± 0.03 ^e | 3.62 ± 0.02 ^a | 70.14 ± 0.16 ^a | 17.02 ± 0.33 ^a |
| 2 | Ziplock | 0.62 ± 0.01 ^a | 9.63 ± 0.05 ^e | 3.30 ± 0.06 ^{cde} | 57.96 ± 0.06 ^d | 13.14 ± 0.55 ^{bc} |
| | Vacuum | 0.51 ± 0.01 ^{cd} | 9.56 ± 0.14 ^e | 3.51 ± 0.04 ^{abc} | 61.87 ± 0.33 ^b | 15.09 ± 0.05 ^{ab} |
| 4 | Ziplock | 0.61 ± 0.01 ^a | 10.41 ± 0.15 ^d | 3.26 ± 0.03 ^{de} | 52.43 ± 0.07 ^e | 12.52 ± 0.12 ^{bcd} |
| | Vacuum | 0.55 ± 0.01 ^{bc} | 9.61 ± 0.03 ^e | 3.42 ± 0.04 ^{abcd} | 59.95 ± 0.15 ^c | 13.68 ± 0.07 ^{bc} |
| 6 | Ziplock | 0.60 ± 0.01 ^a | 11.67 ± 0.11 ^b | 3.11 ± 0.01 ^{ef} | 51.97 ± 0.29 ^e | 10.07 ± 0.17 ^{de} |
| | Vacuum | 0.59 ± 0.01 ^{ab} | 10.63 ± 0.09 ^{cd} | 3.40 ± 0.03 ^{bcd} | 58.72 ± 0.07 ^{cd} | 12.12 ± 0.03 ^{cd} |
| 8 | Ziplock | 0.61 ± 0.01 ^a | 12.84 ± 0.05 ^a | 2.94 ± 0.02 ^f | 50.37 ± 0.07 ^f | 9.16 ± 0.08 ^e |
| | Vacuum | 0.59 ± 0.01 ^a | 11.15 ± 0.06 ^{bc} | 3.39 ± 0.02 ^{cd} | 57.87 ± 0.23 ^d | 12.05 ± 0.11 ^{cd} |

The number with different alphabet (a - f) in the same column indicated significant difference at $p < 0.05$.

CONCLUSION

The pigeon pea pods powder obtained from washed raw material and dried at 60°C could retain high crude fiber contents (31.41 ± 0.26 g/100 g dry weight), total phenolic concentration (2.42 ± 0.11 mg GAE/g dry weight), DPPH radical scavenging activity (45.57 ± 0.07 µmol Trolox / g dry weight) and FRAP value (28.64 ± 0.03 µmol Trolox / g dry weight). Although the powder from unwashed samples had higher total phenolic concentration and DPPH antioxidant activity, washing was widely applied as a necessary processing step to remove contaminants and prepare for further processing to produce high quality final products. Hence, this condition was suggested for the production of high fiber powders from pigeon pea pod. The higher drying temperatures decrease the total crude fiber contents, total phenolic concentration and antioxidant activity. Vacuum-packed samples exhibited higher qualities in terms of total phenolic concentration and antioxidant capacity. In addition, the vacuum-packed pigeon pea pods powder was regarded as microbiologically safe due to lower level of a_w and moisture content for 8 weeks. In a future study, optimizing for extraction of antioxidant ingredients from pigeon pea pod powders by using ultrasonic method should be investigated.

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