

Physical characteristics, nutrients, and antinutrients composition of pigeon pea (*Cajanus cajan* (L.) Millsp.) grown in Indonesia

^{1,2}A'yuni, N.R.L., ¹Marsono, Y., ¹Marseno, D.W. and ^{1,*}Triwitono, P.

¹Department of Food and Agricultural Product Technology, Faculty of Agricultural Technology, Gadjah Mada University, Jalan Flora No.1, Bulaksumur, Yogyakarta 55281, Indonesia

²Agricultural Development Polytechnic of Yogyakarta-Magelang, Jalan Kusumanegara No.2, Umbulharjo, Yogyakarta 55167, Indonesia

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Abstract

Pigeon pea is an underutilized legume in Indonesia. Information about the physical characteristics, nutrients, and antinutrients composition of pigeon pea is needed to develop pigeon pea-based food products. This research aimed to evaluate the physical characteristics, nutrients, and antinutrients composition of pigeon pea grown in different regions of Indonesia, i.e., Bali, Yogyakarta, and Nusa Tenggara Barat (NTB). The results showed that the physical characteristics, nutrients, and antinutrients composition differed significantly. The weight of pigeon pea seeds ranged from 7.49-13.29 g/100 seeds, hydration capacity was 0.07-0.15 g/seed, hydration index was 0.90-1.14, swelling capacity varied from 0.06-0.15 mL/seed, and the swelling index was 1.06-1.54. Pigeon pea was a potential source of protein (23.96-24.20%) and starch (40.55-42.80%). The highest protein content was found in pigeon pea from Yogyakarta, whereas the highest starch content was found in pigeon pea from NTB. The contents of vitamin C, E, A varied from 25.13-28.21 mg/100 g, 67.44-100.51 mg/100 g, and 1,248.83-2,303.86 µg/100 g, respectively. Potassium was the most abundant mineral in pigeon pea (479.66-1,455.51 mg/100 g). Pigeon pea from Yogyakarta had the highest phytic acid content, HCN, tannins at 841.24 ppm, 46.60 ppm, and 378.45 mg/100 g, respectively.

1. Introduction

Leguminosae is the family of a flowering plant comprising 650 to 750 genera and 18,000 to 19,000 species. This family is widely known as legumes, which are classified into four subfamilies: Caesalpinioideae, Mimosoideae, Papilionoideae, and Swartzioideade (Ahmed and Hasan, 2014). Legumes contain 20-40% protein, 50-60% carbohydrate with starch as the main component, 2-3% fat, 0.7-6.2% dietary fibre, vitamins, and minerals (Wani *et al.*, 2016). Legumes also have a low glycemic index value and bioactive compounds with antioxidant properties, so legumes can be a source of functional food (Tayade *et al.*, 2019). Narina *et al.* (2014) and Souza *et al.* (2015) reported that legumes could affect health positively, such as a supplement for diabetes mellitus patients, preventing cardiovascular risk, obesity, and bone disorder. Legumes are typically used as a cereal substitute to increase their finished product's nutrient composition and functional impact (Olagunju *et al.*, 2018). Therefore, legumes can be an alternative to meet nutritional needs and fight several diseases,

especially in developing countries. The developed countries face an increasing demand for protein food sources because of the growing population, inadequate fertile soil, cereal diet, and high food prices (Sharma *et al.*, 2011; Narina *et al.*, 2014; Moussou *et al.*, 2019).

Various countries have used legumes as their primary food sources, such as pigeon pea, chickpea, and lentils in South Asia, kidney beans in Latin America, chickpea, lentils, faba beans in North Africa, and the Middle East (Ahmed and Hasan, 2014). In Indonesia, legumes utilization is still limited to soybean, red kidney bean, and mung bean. On the other hand, Indonesia has various legumes that Indonesian people have not utilized optimally, one of which is pigeon pea. Pigeon pea (*Cajanus cajan* (L.) Millsp.), including the Fabaceae family. Pigeon pea is an annual crop with more drought and high-temperature tolerance than other crops, allowing it to be grown in tropical and subtropical areas. The plant height is about 1-4 meters and has 2 meters of deep taproot (Akande *et al.*, 2010; Al-Saeedi and Hossain, 2015). Pigeon pea pods are flat, dark purple, or

*Corresponding author.

Email: triwitono@ugm.ac.id

green, with 2-9 seeds/pods sometimes hairy or streaked. Seed weight is 4-25 g/100 seeds and varied in colour (Sharma *et al.*, 2011). Pigeon pea in certain countries known by various names, such as guand (Portuguese), tur and arhar (Hindi), gandul (Spanish), ervilba de Congo (Angola), poid d'Angole and poid de Congo (French), red gram, and congo bean (English) (Upadhyaya *et al.*, 2013). In Indonesia, pigeon pea is grown in several areas, including Bali, Yogyakarta, and Nusa Tenggara Barat. Usually, pigeon pea is consumed as a vegetable, and there are still a few pigeon pea-based food products. Therefore, to increase the diversification of pigeon pea-based food products, it is necessary to research the physical characteristics, nutrients, and antinutrients composition of pigeon pea grown in Indonesia.

Information about legume's physical characteristics is useful for processing, storing, and designing processing machinery (Khanbarad *et al.*, 2014). The seed weight and hydration capacity of legumes are linked to the cooking process (Yadav *et al.*, 2018). Legumes with a higher hydration capacity require less cooking time, affecting consumer preference for the seeds (Moussou *et al.*, 2019). The shape and size of legume seeds are significant in designing the machines for sizing and grading (Firatligil-Durmuş *et al.*, 2010). Information about nutrients composition is crucial for the dietary quality assessment, offering a valuable tool for the sector of public health nutrition, development, and implementation of food-based dietary standards (Elmadfa and Meyer, 2010).

Some researchers evaluated the nutrients composition of pigeon pea from Botswana (Amarteifio *et al.*, 2002) and Nigeria (Oshodi *et al.*, 1993; Apata and Ologhobo, 1994; Akande *et al.*, 2010). Some researchers also reported the physical characteristics of pigeon pea from India (Khanbarad *et al.*, 2014; Khan *et al.*, 2017), Botswana (Baryeh and Mangope, 2003), but there is no information yet about hydration capacity, swelling capacity, hydration index, and swelling index of pigeon pea seeds. There has been no research on the physical characteristics, nutrients, and antinutrients composition of pigeon pea from several regions in Indonesia to the author's knowledge. This research aimed to evaluate the physical characteristics, nutrients, and antinutrients composition of pigeon pea grown in various regions of Indonesia, i.e., Bali, Yogyakarta, and Nusa Tenggara Barat.

2. Materials and methods

2.1 Materials

Pigeon pea seeds were obtained from local farmers in Buleleng Bali, Gunungkidul Yogyakarta, and Lombok

Timur Nusa Tenggara Barat (NTB). Pigeon pea seeds were harvested in April-May 2019 (Yogyakarta and NTB) and June 2019 (Bali). For analysis of the nutrients and antinutrients contents, the pigeon pea seeds were ground using a blender (Philips) to become a powder until passing through a sieve no. 40. The pigeon pea powders were packed in aluminium foil packaging with silica gel and then placed in a container at ambient temperature until it was analysed.

2.2 Seed weight, volume, density, and dimensions

Seed weight, volume, and density were determined based on Williams *et al.* (1983). Pigeon pea seeds (100 seeds) were weighed on analytical scales. After that, seeds were moved to a 50 mL measuring cylinder containing 25 mL of distilled water. The difference in distilled water volume after and before the seeds was put into the measuring cylinder is the volume of seeds. Seed density was determined by dividing seed weight by its volume (g/mL). The seed dimensions (length, width, and thickness) were determined using a calliper with a count of at least 0.02 mm.

2.3 Hydration capacity and hydration index

Determination of hydration capacity and hydration index based on Williams *et al.* (1983). The seeds of pigeon pea (100 seeds) were weighed and placed into a beaker glass together with distilled water (100 mL). The beaker glass was enclosed with aluminium foil then left for 24 hrs at ambient temperature. The next day, the seeds were drained, redundant water was separated with filter paper, and the swollen seeds were weighed again. Hydration capacity and hydration index were calculated as follows:

Hydration capacity per seed = (weight of seed after - before soaking)/100

Hydration index = hydration capacity per seed/average weight of seed

2.4 Swelling capacity and swelling index

Determination of swelling capacity and swelling index refers to Williams *et al.* (1983). After re-weighing the swollen seeds, they were put in a 100 mL measuring cylinder containing 50 mL of distilled water. Their volume was measured again to determine swelling capacity and swelling index, accordingly to this equation:

Swelling capacity per seed = (volume of seed after - before soaking)/100

Swelling index = swelling capacity per seed/average volume of seed

2.5 Seed colour

The values of a^* (+ a^* redness, - a^* greenness), b^* (+ b^* yellowness, - b^* blueness), and L (lightness) were determined using chromameter CR-400 (Konica Minolta, Japan).

2.6 Proximate composition, starch content, and gross energy

Proximate analysis (moisture, ash, fat, protein) was conducted using the AOAC method (1995). The moisture content was measured by drying the sample in an oven (105°C) until the sample weight was constant. The crude fat content was measured by extracting the sample with petroleum ether in an extractor of Soxhlet. The crude protein content was measured using the Kjeldahl method; then, the crude protein content was calculated by multiplying nitrogen content by 6.25. The ash content was measured using the gravimetric method by comparing the sample weight before and after ashing in the furnace. Carbohydrate by difference was calculated by $100 - (\text{moisture}\% + \text{fat}\% + \text{ash}\% + \text{protein}\%)$. The direct acid hydrolysis method was used to determine starch content, followed by the determination of glucose using a conversion factor of 0.9 (AOAC, 1995). The gross energy was measured using a bomb calorimeter (Gallenkamp auto bomb calorimeter), and benzoic acid was used as a calibration standard (Moussou *et al.*, 2019).

2.7 Crude fibre content

Crude fibre analysis was performed using the AOAC method (1995). A gram (1 g) of the fat-free sample was added to 200 mL of 1.25% H_2SO_4 . The suspension was heated at 100°C for 30 mins while being stirred. The suspension was filtered with filter paper then washed using hot distilled water until neutral. The residue was transferred quantitatively into the Erlenmeyer, and then the rest was washed with 200 mL of 1.25% NaOH until all residues entered the Erlenmeyer. The residue was heated in a water bath for 30 minutes at 100°C while being stirred, then filtered using filter paper with a constant weight (a). The residue was washed using 15 mL of 96% ethanol then washed with hot distilled water up to neutral. The residue in the filter paper was dried at 100 °C until it reached a constant weight (b). Crude fibre content was calculated as follow:

$$\% \text{ Crude fibre} = \frac{b-a}{\text{weight of sample}} \times 100\%$$

2.8 Minerals content

Determination of minerals content (Ca, Mg, Zn, Cu, K, and Na) was adopted from the AOAC method (1995). Sample preparation for minerals content analysis used

the wet digestion method. The sample was digested using concentrated HNO_3 (1:3) then heated until the solution becomes clear and a dense white fume appeared. The sample was cooled, diluted with 50 mL of distilled water then filtered using Whatman filter paper. The filtrates were collected in a 100 mL volumetric flask, and the volume was adjusted with distilled water. The resulting solution was then measured for its absorbance using atomic absorption spectrophotometry (Perkin-Elmer 3110). The content of phosphorus was measured using a molybdovanadate method (AOAC, 1995). The digested sample (1 mL) was placed into a volumetric flask (10 mL), then 3 mL of vanadate-molybdate solution was added, followed by distilled water up to the mark. The solution was vortexed and then read its absorbance at 410 nm. For determination of iron content, 1 mL of digested sample was put in a 10 mL volumetric flask, followed by 2 mL of 1.5 M ammonium thiocyanate and distilled water up to the mark. Its absorbance was determined at 510 nm, and the iron content was determined from the Fe standard curve (Woods and Mellon, 1941).

2.9 Vitamin A content

Vitamin A content was determined as β carotene using the spectrophotometry method (AOAC, 1995). Sample (5 g) was extracted using petroleum ether and acetone (1:1). The extract was separated from the solvent using a separating funnel by adding distilled water. The top layer, which is the carotene fraction, was added with Na_2SO_4 anhydrate to absorb the remaining distilled water, added petroleum ether up to a volume of 25 mL, then the absorbance was determined at 450 nm and used β carotene as a standard.

2.10 Vitamin C content

Vitamin C content was determined using the iodine titration method (Jacobs, 1962). The sample was placed into a 100 mL volumetric flask, and distilled water was added up to the mark, then the filtrate was filtered to separate it. The filtrate (5 mL) was placed into Erlenmeyer, added 2 mL of 1 % amyllum and 20 mL of distilled water, then titrated with 0.01 N iodine standard. Calculation of vitamin C content was determined by standardizing iodine solution, in which the equivalent of 1 mL of 0.01 N iodine is 0.88 mg of ascorbic acid.

2.11 Vitamin E content

Vitamin E content was determined as the total tocopherol (AOAC, 1988). The sample (1 g) was dissolved using N-hexane. An aliquot (1 mL) of sample solution was taken, then added 3.5 mL of 0.07% 2,2 bipyridine solution and 0.5 mL of 0.02% FeCl_3 . The solution was diluted to 10 mL using 96% ethanol, and

then the absorbance was determined at 520 nm and used tocopherol as a standard.

2.12 Phytic acid content

The content of phytic acid was determined based on Wheeler and Ferrel method (1971). The sample (2 g) was extracted with 50 mL of 3% TCA for 30 mins, then centrifuged. The supernatant was separated, then 10 mL was taken and put into a centrifuge tube and added with 4 mL of FeCl₃ solution, then boiled in a water bath for 45 mins. The aliquot was centrifuged, and the supernatant was separated. The precipitate was washed twice using 20-25 mL of 3% TCA, boiled in a water bath for 10-15 mins, centrifuged again, and the supernatant was separated. The precipitate was washed once with distilled water, centrifuged for 10-15 mins, and the supernatant was separated. The precipitate was dispersed with distilled water and 3 mL of 1.5 N NaOH. The precipitate was diluted to 30 mL and boiled in a water bath for 30 mins, then filtered. The precipitate was dissolved in hot HNO₃ then diluted to 100 mL. An aliquot (5 mL) was put into the 100 mL volumetric flask, followed by 60 mL of distilled water, 20 mL of 1.5 M KSCN, and diluted to the mark. The solution was read for absorbance at 480 nm. The phytic acid can be determined based on Fe's calculation from the standard curve with the molecular ratio of Fe:P = 4:6.

2.13 Tannins content

Tannins content was determined by Folin Denis colourimetric method (Harborne, 1973). Sample (5 g) was put into a 100 mL volumetric flask, then distilled water was added to the mark. The mixture was shaken until homogenous, then was filtered to obtain the extract. Put 1 mL of extract, 0.5 mL of Folin Denis reagent, 1 mL of saturated NaCO₃, and distilled water until the volume reached 10 mL. The mixture was vortexed, then its absorbance was determined at 730 nm, and pure tannic acid was used as a standard. The tannins content was determined using the linear regression equation, expressed in mg/100 g from the standard curve.

2.14 Hydrogen Cyanide (HCN) content

The HCN content was determined using the alkaline picrate method (Williams and Edwards, 1980). Sample (5 g) was added with distilled water (50 mL). The mixture was shaken and filtered to obtain the extract. The extract (1 mL) was added with 4 mL of alkaline picrate solution; then, this was incubated in a water bath until it formed reddish-brown colour. The solution was determined for its absorbance at 480 nm and used potassium cyanide (KCN) as a standard. The HCN content was quantified based on the linear regression equation from the standard curve, and the result was

given as ppm.

2.15 Statistical analysis

Data analysis used a one-way Analysis of Variance (ANOVA) with a significant level of 5%. If a significant difference were identified, the Duncan Multiple Range (DMRT) test would then proceed. SPSS software version 23 for statistical analysis.

3. Results and discussion

3.1 Physical characteristics

The physical characteristics of pigeon pea seeds are presented in Table 1. The Indonesian pigeon pea dimensions were almost the same as pigeon pea from India and Botswana. Pigeon pea from India had length 5.37-6.24 mm, width 4.97-5.67 mm, and thickness 4.06-4.60 mm (Khanbarad *et al.*, 2014), while pigeon pea from Botswana had length 5.074-6.502 mm and thickness 3.365-5.091 mm (Baryeh and Mangope, 2003). The dimensions of pigeon pea from Indonesia ranged from 5.07-5.99 mm (length), 4.83-5.58 mm (width), and 4.07-5.05 mm (thickness). The weight and volume of 100 seeds ranged from 7.49-13.29 g and 6.00-9.83 mL, respectively. Based on this result, pigeon pea seeds from Bali had the largest dimensions, weight, and volume, while the pigeon pea from Yogyakarta was the opposite. This difference due to the volume depends on the seed dimensions consisting of length, width, and thickness, so that the bigger the dimensions, the larger the volume (Khanbarad *et al.*, 2014). The density ranged from 1.25-1.35 g/mL, with pigeon pea from Bali, having the highest density and pigeon pea from Yogyakarta having the lowest. The pigeon pea density was greater than water, which shows that pigeon pea seeds will not float on the water during cleaning (Ghadge and Prasad, 2012).

Pigeon pea seed colour was not significantly different for a* (0.76-0.95) and b* (1.52-2.15) values. Based on the L value (30.70-31.64), pigeon pea seed colour tends to be dark. The colour difference can indicate the number of antinutrient compounds in pigeon pea seeds. Antinutrient compounds primarily present in the dark seed genotypes commonly grow in Asia, different from the African pigeon pea has a cream or white colour, with fewer antinutrient compounds (Odeny, 2007). In this research, pigeon pea from Bali had the lowest antinutrient content, and the colour of pigeon pea seeds from Bali tends to be lighter than other pigeon pea seeds.

Pigeon pea seeds had the hydration index, swelling index, hydration capacity, and swelling capacity ranged from 0.90-1.14, 1.06-1.54, 0.07-0.15 g/seed, and 0.06-0.15 mL/seed, respectively. Pigeon pea seeds from Bali

Table 1. Physical characteristics of pigeon pea seeds

Physical characteristics	Pigeon pea seeds		
	Bali	Yogyakarta	NTB
Length (mm)	5.99±0.21 ^a	5.07±0.11 ^c	5.44±0.08 ^b
Width (mm)	5.58±0.20 ^a	4.83±0.13 ^b	5.31±0.14 ^a
Thickness (mm)	5.05±0.14 ^a	4.07±0.11 ^c	4.65±0.09 ^b
Weight (g/100 seeds)	13.29±0.21 ^a	7.49±0.07 ^c	10.20±0.18 ^b
Volume (mL/100 seeds)	9.83±0.29 ^a	6.00±0.00 ^c	7.67±0.29 ^b
Density (g/mL)	1.35±0.02 ^a	1.25±0.01 ^b	1.33±0.03 ^a
L	31.64±0.44 ^a	30.70±0.16 ^b	30.72±0.11 ^b
a*	0.95±0.06 ^a	0.81±0.15 ^a	0.76±0.20 ^a
b*	2.15±0.28 ^a	1.75±0.43 ^a	1.52±0.16 ^a
Hydration capacity (g/seed)	0.15±0.00 ^a	0.07±0.00 ^c	0.11±0.00 ^b
Hydration index	1.14±0.02 ^a	0.90±0.03 ^c	1.07±0.01 ^b
Swelling capacity (mL/seed)	0.15±0.00 ^a	0.06±0.01 ^c	0.11±0.00 ^b
Swelling index	1.54±0.08 ^a	1.06±0.10 ^c	1.39±0.01 ^b

Values are presented as mean±SD. Values with different superscripts within the same row are significantly different ($p < 0.05$).

had the highest swelling capacity, swelling index, hydration capacity, and hydration index; therefore, it requires less cooking duration than other pigeon pea seeds (Bishnoi and Khetarpaul, 1993). These parameters indicated that pigeon pea seeds from Bali have the most permeable and soft seed coat than the other seeds (Seena and Sridhar, 2005). Pigeon pea seeds from Yogyakarta had the lowest hydration index, swelling index, hydration capacity, and swelling capacity. These parameters showed that pigeon pea seeds from Yogyakarta have a low water absorption capacity, which is influenced by the composition of the seed, cell wall structure, and compactness of the seed cells (Kaur et al., 2005). Pigeon pea from Yogyakarta had the highest crude fibre content of 5.50% (Table 2), causing the thicker coat seed, thus inhibiting water absorption. A similar result was reported on chickpea (Kaur et al., 2005). Pigeon pea from Yogyakarta also had the highest tannins content of 378.45 mg/100 g (Table 4). Tannins can bind to proteins in cell walls and the middle lamella, causing lignification, increasing the cell wall thickness (Yousif et al., 2003).

3.2 Proximate composition, starch content, and gross energy

The nutrient composition of pigeon pea seeds from different regions is shown in Table 2. According to these data, the biochemical composition of Indonesian pigeon pea was substantially different. In this report, all pigeon pea seeds are protein and starch sources. The pigeon pea protein content ranged from 23.96-24.20%, with pigeon pea from Yogyakarta, having the highest protein content. Pigeon pea protein content from Indonesia was higher than pigeon pea from Nigeria of 21.03% (Akande et al., 2010) and Botswana of 19.0-21.7% (Amarteifio et al., 2002). It showed that pigeon pea protein content could be affected by variations in growing locations. According to Bárta et al. (2004), growing location is the most important factor influencing the variability of crude protein content. Seeds grown in locations with a higher soil supply of plant-available nitrogen will contain higher crude protein. Starch content ranged from 40.55-42.80%, with pigeon pea from NTB having the highest starch content; this showed that the environment influences starch biosynthesis, as reported by Beckles and Thitisaksakul (2014). Pigeon pea starch content was

Table 2. Proximate composition, starch content, and gross energy of pigeon pea seeds

Components	Pigeon pea seeds		
	Bali	Yogyakarta	NTB
Moisture (% wb)	11.08±0.07 ^c	11.29±0.02 ^b	11.92±0.04 ^a
Protein (% db)	24.10±0.03 ^b	24.20±0.04 ^a	23.96±0.05 ^c
Fat (% db)	1.51±0.07 ^a	1.61±0.02 ^b	1.60±0.02 ^b
Ash (% db)	4.92±0.03 ^a	4.36±0.01 ^c	4.68±0.01 ^b
Carbohydrate by difference (% db)	69.48±0.13 ^b	69.82±0.03 ^a	69.76±0.04 ^a
Starch (% db)	42.36±0.20 ^b	40.55±0.04 ^c	42.80±0.06 ^a
Crude fiber (% db)	4.41±0.06 ^b	5.50±0.06 ^a	3.58±0.16 ^c
Gross energy (cal/g)	3,799.40±17.54 ^b	3,927.59±96.25 ^a	3,875.71±25.04 ^{ab}

Values are presented as mean±SD. Values with different superscripts within the same row are significantly different ($p < 0.05$).

almost the same as the starch content of legumes reported by Moussou *et al.* (2019), i.e., 42.29%, 43.44%, 37.65%, 38.89%, and 44.40% for chickpea, lentil, faba bean, common bean, and pea. The crude fibre content of pigeon pea varied from 3.58-5.50%, with the highest crude fibre content, was found in pigeon pea from Yogyakarta. This result was lower than crude fibre content from Botswana (9.8-13.0%) (Amarteifio *et al.*, 2002) and Nigeria (7.16%) (Akande *et al.*, 2010). Gross energy is the amount of potential energy in foodstuffs that can't be directly used by humans. Humans can use gross energy contained in foodstuffs if it is processed into available energy in the body by digestion, absorption, and metabolism (Priska *et al.*, 2020). The gross energy of pigeon pea ranged from 3,799.40-3,927.59 cal/g, lower than the reported gross energy of other legumes, which ranged from 4,927.19-5,214.22 cal/g (Moussou *et al.*, 2019). According to Priska *et al.* (2020), the value of gross energy is affected by the nutritional content of foodstuffs. Foodstuffs with more nutritional content have a higher gross energy value.

3.3 Vitamins and minerals contents

Pigeon pea seeds also contain vitamins and minerals, which are micronutrients because the body needs these components in small amounts (Gharibzahedi and Jafari, 2017). Vitamins A, C, and E are antioxidants because they contain carotenoids, ascorbic acid, and tocopherol, respectively (Frias *et al.*, 2005). Based on Table 3, the vitamin C content of pigeon pea seeds was 25.13-28.21 mg/100 g. This value was higher than vitamin C content in pigeon pea from Nigeria ranging from 0.9-1.1 mg/100 g, cowpea varied from 0.5-0.9 mg/100 g, *Sphenostylis sternocarpa* 0,8 mg/100 g (Obboh, 2006), *Vigna mungo* 5.20-7.14 mg/100 g (Sorris *et al.*, 2010), pea seeds 8.01-11.01 mg/100 g, and lupine seeds 0.51-0.81 mg/100 g (Janeczko *et al.*, 2015). The vitamin C intake of 10 mg

per day is sufficient to avoid scurvy, a pathological disorder leading to the fragility of blood vessels, damage to connective tissues, weakness, and, eventually, death (Grosso *et al.*, 2013). In this study, the vitamin A (β carotene) content of pigeon pea was 1,248.83-2,303.86 μ g/100 g, higher than pea seeds (6-333 μ g /100 g), and lupine seeds (4-279 μ g /100 g) (Janeczko *et al.*, 2015). In humans, β carotene is the primary precursor of vitamin A, plays a role in preserving vision and inhibiting degenerative diseases (Jeyakodi *et al.*, 2018). The vitamin E content (total tocopherol) in pigeon pea ranged from 67.44-100.51 mg/100 g (Table 3). This value was higher than the vitamin E (total tocopherol) content of common bean (2.67-4.98 mg/100 g), broad bean (5.45-6.19 mg/100 g), chickpea (8.67-11.3 mg/100 g), lentil (4.02-5.46 mg/100 g), soybean (13.1-14.2 mg/100 g), *Lupinus albus* (6.32-13.4 mg/100 g), *Lupinus angustifolius* (7.35-9.54 mg/100 g), and *Lupinus mutabilis* (10.3 mg/100 g). Tocopherols are strong antioxidants because they can disrupt the process of unsaturated lipid peroxidation by entrapping intermediates of hydroperoxide (Boschin and Arnoldi, 2011). Differences in vitamin content can be influenced by many factors, including variety, location, and analysis procedure. Mainly, a variability of 15-20% between different quantification methods has been recorded (Stokes *et al.*, 2018; Groth *et al.*, 2020).

Mineral consist of macromineral and micromineral. The macromineral is required for more than 100 mg/dl, and the micromineral is needed for less than 100 mg/dl (Soetan *et al.*, 2010). According to the mineral's composition (Table 3), the pigeon pea from Indonesia had various minerals content and differed significantly among pigeon pea. This result showed that the different locations cause minerals content variations, appropriate to what was reported by Apata and Ologhobo (1994) and Moussou *et al.* (2019). The location difference can cause

Table 3. Vitamins and minerals contents of pigeon pea seeds

Components	Pigeon pea seeds		
	Bali	Yogyakarta	NTB
Vitamin C (mg/100 g)	27.48±0.03 ^b	28.21±0.05 ^a	25.13±0.11 ^c
Vitamin E (mg/100 g)	71.27±0.97 ^b	100.51±2.50 ^a	67.44±0.64 ^c
Vitamin A (μ g/100 g)	2,303.86±33.65 ^a	1,902.79±46.78 ^b	1,248.83±34.27 ^c
P (mg/100 g)	378.61±1.51 ^c	406.24±0.95 ^b	411.43±1.50 ^a
Fe (mg/100 g)	35.18±0.35 ^a	19.70±0.18 ^b	20.25±0.34 ^b
Ca (mg/100 g)	87.21±1.27 ^c	128.85±0.76 ^a	95.23±0.86 ^b
Mg (mg/100 g)	142.62±2.23 ^a	136.97±1.51 ^b	135.65±1.18 ^b
Zn (mg/100 g)	5.03±0.69 ^a	3.41±0.08 ^b	3.25±0.08 ^b
Cu (mg/100 g)	1.03±0.02 ^b	1.23±0.04 ^a	0.93±0.05 ^c
K (mg/100 g)	479.66±7.96 ^c	1,275.61±19.53 ^b	1,455.51±31.99 ^a
Na (mg/100 g)	91.68±1.57 ^c	103.57±2.31 ^a	95.51±0.89 ^b
Na/K ratio	0.19	0.08	0.07

Values are presented as mean±SD. Values with different superscripts within the same row are significantly different ($p < 0.05$).

differences in climate, geology, agricultural techniques, and soil composition (Di Bella *et al.*, 2016).

The potassium content varied from 479.66-1,455.51 mg/100 g, phosphorus 378.61-411.43 mg/100 g, magnesium 135.65-142.62 mg/100 g, calcium 87.21-128.85 mg/100 g and sodium 91.68-103.57 mg/100 g. In this study, sodium and calcium contents were lower than the other macrominerals. These results were comparable to those reported by Apata and Ologhobo (1994) that sodium and calcium contents in kidney bean, pigeon pea, Bambara groundnut, lima bean, and jack bean were lower than other macro-minerals. Based on the data, potassium was the main mineral in pigeon pea. The presence of potassium in the body can increase iron utilization and control hypertension through diuretics and for people who experience uncontrolled potassium excretion via body fluids (Elinge *et al.*, 2012). The phosphorus content of pigeon pea was lower than faba bean (1,187.97 mg/100 g), chickpea (797.71 mg/100 g), and common bean (503.92 mg/100 g) (Moussou *et al.*, 2019). The high dietary phosphorus burden is not suitable for chronic kidney sufferers. It can deteriorate renal osteodystrophy, cardiovascular injury, hyperparathyroidism, and encourage vascular calcification (Kalantar-Zadeh *et al.*, 2010). The Na/K ratio of pigeon pea was low (0.07-0.19). This value was lower than the Na/K ratio of *Vigna mungo* (0.16 - 0.24) (Soriso *et al.*, 2010). The Na/K ratio is crucial from a nutritional perspective because a high Na/K ratio of diet is associated with hypertension incidence (Moussou *et al.*, 2019). It is recommended less than one (Soriso *et al.*, 2010). Thus, pigeon pea has the potential to be developed as a diet for people with hypertension. The magnesium content of pigeon pea in this work was higher than pigeon pea from Botswana, 113-127 mg/100 g (Amerteifio *et al.*, 2002), and Nigeria, 110 mg/100 g (Oshodi *et al.*, 1993). Magnesium is a cofactor of some 300 enzymes that govern the body's metabolisms. Chronic deficiency of magnesium occurs when serum magnesium content is less than 0.75 mmol/L, known to increase the risk of hypertension, atherosclerosis, cardiac arrhythmias, stroke, lipid metabolism changes, insulin resistance, metabolic syndrome, type 2 diabetes, osteoporosis, depression, and neuropsychiatric conditions (Gröber *et al.*, 2015). The calcium content of pigeon pea from Indonesia was lower than pigeon pea

from Botswana, 120-167 mg/100 g (Amerteifio *et al.*, 2002) but higher than pigeon pea from Nigeria, 81.4 mg/100 g (Oshodi *et al.*, 1993). Calcium plays an important role in blood clotting, nerve transmission, muscle contraction, and bone health (Peters and Martini, 2010; Elinge *et al.*, 2012).

The micromineral content consisting of iron, zinc, and copper was 19.70-35.18 mg/100 g, 3.25-5.03 mg/100 g, and 0.93-1.23 mg/100 g, respectively. Among microminerals, iron was the most abundant in pigeon pea. Iron plays a role in producing red blood cells in all body organs, including in the brain, and supporting haemoglobin synthesis in developing fetuses and young children (Georgieff *et al.*, 2019). The zinc content of pigeon pea from Bali was higher than pigeon pea from Nigeria, 4.1 mg/100 g (Oshodi *et al.*, 1993), comparable with chickpea (5.07 mg/100 g) and common bean (5.08 mg/100 g) (Moussou *et al.*, 2019). Zinc is essential for maintaining the system of immune in the body. The zinc deficiency leads to a massive decrease in the adaptive and innate immune and the promotion of inflammatory systemic (Cabrera, 2015). Copper had the lowest content among other microminerals. In this study, pigeon pea's copper content was slightly lower than the copper content of pigeon pea from Nigeria, 1.3 mg/100 g (Oshodi *et al.*, 1993). Intake copper of 0.6-3 mg/day can reduce the risk of cancer, cognitive decline, arthritis, and cardiovascular disease (Bost *et al.*, 2016).

3.4 Antinutrients content

Pigeon pea, like other legumes, contains antinutrients. Antinutrients are generally secondary metabolites produced by plants for their defence (Popova and Mihaylova, 2019). Besides causing problems on the bioavailability of nutrients, antinutrients also provide beneficial effects on health (Bora, 2014). According to Table 4, there were variations in the content of antinutrients among pigeon pea seeds, caused by differences in location, climatic conditions, and soil type (Urbano *et al.*, 2000).

Hydrogen cyanide (HCN) can cause central nervous system dysfunction, respiratory failure, and heart attacks (Sinha and Khare, 2017). The hydrogen cyanide (HCN) content of Indonesian pigeon pea ranged from 30.77 to 46.60 ppm. This result was almost the same as the HCN

Table 4. Antinutrients content of pigeon pea seeds

Components	Pigeon pea seeds		
	Bali	Yogyakarta	NTB
HCN (ppm)	30.77±0.62 ^c	46.60±0.65 ^a	43.73±0.48 ^b
Phytic acid (ppm)	325.25±35.63 ^b	841.24±27.94 ^a	344.45±48.48 ^b
Tannins (mg/100g)	336.17±3.69 ^c	378.45±2.44 ^a	368.96±4.41 ^b

Values are presented as mean±SD. Values with different superscripts within the same row are significantly different ($p < 0.05$).

content of pigeon pea from Nigeria (40.50 ppm) but lower than cowpea (83.81 ppm) (Onwuka, 2006). The HCN content of Indonesian pigeon pea is still below the lethal dose, 36 mg/100 g, or 360 ppm (Kalpanadevi and Mohan, 2013). Soaking pigeon pea seeds for 12 hrs, followed by boiling for 60 mins, can eliminate almost HCN (Onwuka, 2006) so that pigeon pea is relatively safe for consumption.

Consumption of phytate decreases mineral consumption because it can chelate some minerals, such as Ca^{2+} , Mg^{2+} , Fe^{2+} , and Zn^{2+} (Urbano et al., 2000). Consumption of it at low concentrations can reduce blood glucose levels, cholesterol, and triacylglycerol (Popova and Mihaylova, 2019). The phytic acid content of Indonesian pigeon pea (325.25-841.24 ppm) was higher than pigeon pea from India (73.4 ppm) (Sangronis and Machado, 2007) but lower than pigeon pea from Nigeria (20,000-24,000 ppm) (Oboh, 2006), chickpea (15,400 ppm), lentil (24,000 ppm), faba bean (24,000 ppm), common bean (21,500 ppm), pea (12,100 ppm) (Moussou et al., 2019), and soybean (5,100 to 24,500 ppm) (Sharma et al., 2013).

The tannins content of Indonesian pigeon pea ranged from 336.17 - 378.45 mg/100 g, lower than the tannins content of Nigerian pigeon pea (1,600 mg/100 g) (Onwuka, 2006), Indian pigeon pea (1,400 mg/100 g), white bean *Phaseolus vulgaris* (1,700 mg/100 g), black bean *Phaseolus vulgaris* (2,100 mg/100 g) (Sangronis and Machado, 2007), soybean (1,110 - 1,880 mg/100 g) (Sharma et al., 2013), common bean (410.93 mg/100 g) (Moussou et al., 2019) but higher than jack bean (82.5 mg/100 g) (Doss et al., 2011), chickpea (165.68 mg/100 g), lentil (282.30 mg/100 g), faba bean (151.13 mg/100 g), and pea (161.26 mg/100 g) (Moussou et al., 2019). Excessive consumption of tannins can cause the inactivation of enzymes that play a role in protein absorption (Popova and Mihaylova, 2019). Tannins and enzymes can form complex compounds, thus inhibiting protein digestibility (Sharma et al., 2013). However, tannins also have beneficial health effects. Kumari and Jain (2012) reported positive effects of tannins as cardioprotective, anti-inflammatory, anticarcinogenic, and antimutagenic. Tannins have health effects because of their capacity to be free radical scavengers and to activate antioxidant enzymes. Tannins can also decrease blood glucose content by increasing glucose uptake. Thus, it has the potential to be a treatment for type 2 diabetes mellitus patients.

4. Conclusion

Pigeon pea grown in different regions of Indonesia have significantly different physical characteristics, nutrients, and antinutrients contents. Pigeon pea from

Bali has the largest size, weight, and volume. Pigeon pea from Yogyakarta has the highest protein content, while pigeon pea from NTB has the highest starch content. Pigeon pea is a potent mineral source. A low Na/K ratio of pigeon pea (0.07-0.19) can prevent high blood pressure, especially pigeon pea from NTB, which has the lowest Na/K ratio. The highest antinutrient content is found in Yogyakarta pigeon pea. The presence of vitamins A, C, E, and tannins indicate the antioxidant properties of pigeon pea so pigeon pea has the potential to be developed into functional food.

Conflict of interest

The authors declare no conflict of interest.

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References

- Ahmed, S. and Hasan, M.M. (2014). Legumes: An overview. *Journal of Pharmacy and Pharmaceutical Sciences*, 2(1), 34-38.
- Akande, K.E., Abubakar, M.M., Adegbola, T.A., Bogoro, S.E. and Doma, U.D. (2010). Chemical evaluation of the nutritive quality of pigeon pea [*Cajanus cajan* (L.) Millsp.]. *International Journal of Poultry Science*, 9(1), 63-65. <https://doi.org/10.3923/ijps.2010.63.65>
- Al-Saeedi, A.H. and Hossain, M.A. (2015). Total phenols, total flavonoids contents and free radical scavenging activity of seeds crude extracts of pigeon pea traditionally used in Oman for the treatment of several chronic diseases. *Asian Pacific Journal of Tropical Disease*, 5(4), 316-321. [https://doi.org/10.1016/S2222-1808\(14\)60790-8](https://doi.org/10.1016/S2222-1808(14)60790-8)
- Amarteifio, J.O., Munthali, D.C., Karikari, S.K. and Morake, T.K. (2002). The composition of pigeon peas (*Cajanus cajan* (L.) Millsp.) grown in Botswana. *Plant Foods for Human Nutrition*, 57(2), 173-177. <https://doi.org/10.1023/A:1015248326920>
- AOAC. (1988). Official Methods of Analysis of the Association of Official Analytical Chemists. Washington, USA: Association of Official Analytical Chemists.
- AOAC. (1995). Official Methods of Analysis of AOAC

- International. 16th ed. Washington, USA: AOAC International.
- Apata, D.F. and Ologhobo, A.D. (1994). Biochemical evaluation of some Nigerian legume seeds. *Food Chemistry*, 49(4), 333-338. [https://doi.org/10.1016/0308-8146\(94\)90001-9](https://doi.org/10.1016/0308-8146(94)90001-9)
- Bárta, J., Kalinová, J., Moudrý, J. and Čurn, V. (2004). Effects of environmental factors on protein content and composition in buckwheat flour. *Cereal Research Communications*, 32(4), 541-548. <https://doi.org/10.1007/BF03543346>
- Baryeh, E.A. and Mangope, B.K. (2003). Some physical properties of QP-38 variety pigeon pea. *Journal of Food Engineering*, 56(1), 59-65. [https://doi.org/10.1016/S0260-8774\(02\)00148-6](https://doi.org/10.1016/S0260-8774(02)00148-6)
- Beckles, D.M. and Thitisaksakul, M. (2014). How environmental stress affects starch composition and functionality in cereal endosperm. *Starch/Stärke*, 66 (1-2), 58-71. <https://doi.org/10.1002/star.201300212>
- Bishnoi, S. and Khetarpaul, N. (1993). Variability in physico-chemical properties and nutrient composition of different pea cultivars. *Food Chemistry*, 47(4), 371-373. [https://doi.org/10.1016/0308-8146\(93\)90179-J](https://doi.org/10.1016/0308-8146(93)90179-J)
- Bora, P. (2014). Anti-nutritional factors in foods and their effects. *Journal of Academia and Industrial Research*, 3(6), 285-290.
- Boschin, G. and Arnoldi, A. (2011). Legumes are valuable sources of tocopherols. *Food Chemistry*, 127(3), 1199-1203. <https://doi.org/10.1016/j.foodchem.2011.01.124>
- Bost, M., Houdart, S., Oberli, M., Kalonji, E., Huneau, J. and Margaritis, I. (2016). Dietary copper and human health: Current evidence and unresolved issues. *Journal of Trace Elements in Medicine and Biology*, 35, 107-115. <https://doi.org/10.1016/j.jtemb.2016.02.006>
- Cabrera, A.J.R. (2015). Zinc, aging, and immunosenescence: An overview. *Pathobiology of Aging and Age-related Diseases*, 5(1), 1-9. <https://doi.org/10.3402/pba.v5.25592>
- Di Bella, G., Naccari, C., Bua, G.D., Rastrelli, L., Lo Turco, V., Potortì, A.G. and Dugo, G. (2016). Mineral composition of some varieties of beans from Mediterranean and Tropical areas. *International Journal of Food Sciences and Nutrition*, 67(3), 239-248. <https://doi.org/10.3109/09637486.2016.1153610>
- Doss, A., Pugalenti, M., Vadivel, V.G., Subhashini, G. and Anitha Subash, R. (2011). Effects of processing technique on the nutritional composition and antinutrients content of under-utilized food legume *Canavalia ensiformis* L.DC. *International Food Research Journal*, 18(3), 965-970.
- Elinge, C.M., Muhammad, A., Atiku, F.A., Itodo, A.U., Peni, I.J., Sanni, O.M. and Mbongo, A.N. (2012). Proximate, mineral and antinutrient composition of pumpkin (*Cucurbita pepo* L) seeds extract. *International Journal of Plant Research*, 2(5), 146-150. <https://doi.org/10.5923/j.plant.20120205.02>
- Elmadfa, I. and Meyer, A.L. (2010). Importance of food composition data to nutrition and public health. *European Journal of Clinical Nutrition*, 64(S3), S4-S7. <https://doi.org/10.1038/ejcn.2010.202>
- Firatligil-Durmuş, E., Šárka, E., Bubník, Z., Schejbal, M. and Kadlec, P. (2010). Size properties of legume seeds of different varieties using image analysis. *Journal of Food Engineering*, 99(4), 445-451. <https://doi.org/10.1016/j.jfoodeng.2009.08.005>
- Frias, J., Miranda, M. L., Doblado, R. and Vidal-Valverde, C. (2005). Effect of germination and fermentation on the antioxidant vitamin content and antioxidant capacity of *Lupinus albus* L. var. Multolupa. *Food Chemistry*, 92(2), 211-220. <https://doi.org/10.1016/j.foodchem.2004.06.049>
- Georgieff, M.K., Krebs, N.F. and Cusick, S.E. (2019). The benefits and risks of iron supplementation in pregnancy and childhood. *Annual Review of Nutrition*, 39, 121-146. <https://doi.org/10.1146/annurev-nutr-082018-124213>
- Ghadge, P.N. and Prasad, K. (2012). Some physical properties of rice kernels: Variety PR-106. *Journal of Food Processing and Technology*, 3(8), 1000175. <https://doi.org/10.4172/2157-7110.1000175>
- Gharibzahedi, S.M.T. and Jafari, S.M. (2017). The importance of minerals in human nutrition: Bioavailability, food fortification, processing effects and nanoencapsulation. *Trends in Food Science and Technology*, 62, 119-132. <https://doi.org/10.1016/j.tifs.2017.02.017>
- Gröber, U., Schmidt, J. and Kisters, K. (2015). Review: Magnesium in prevention and therapy. *Nutrients*, 7 (9), 8199-8226. <https://doi.org/10.3390/nu7095388>
- Grosso, G., Bei, R., Mistretta, A., Marventano, S., Calabrese, G., Masuelli, L., Giganti, M.G., Modesti, A., Galvano, F. and Gazzalo, D. (2013). Effects of vitamin C on health: A review of evidence. *Frontiers in Bioscience*, 18(3), 1017-1029. <https://doi.org/10.2741/4160>
- Groth, S., Wittmann, R., Longin, C.F.H. and Böhm, V. (2020). Influence of variety and growing location on carotenoid and vitamin E contents of 184 different durum wheat varieties (*Triticum turgidum* ssp. durum) in Germany. *European Food Research*

- and Technology, 246(10), 2079–2092. <https://doi.org/10.1007/s00217-020-03557-1>
- Harborne, J.B. (1973). Photochemical Analysis: A Guide to Modern Techniques in Plant Analysis. New York, USA: Chapman and Hall.
- Jacobs, M.B. (1962). The Chemical Analysis of Food and Food Products. 3rd ed. New York, USA: D. Van Nostrand Company Inc.
- Janeczko, A., Dziurka, M., Ostrowska, A., Biesaga-Koscielniak, J. and Koscielniak, J. (2015). Improving vitamin content and nutritional value of legume yield through water and hormonal seed priming. *Legume Research*, 38(2), 185-193. <https://doi.org/10.5958/0976-0571.2015.00072.7>
- Jeyakodi, S., Krishnakumar, A. and Chellappan, D.K. (2018). Beta carotene-therapeutic potential and strategies to enhance its bioavailability. *Nutrition and Food Science International Journal*, 7(4), 1-6. <https://doi.org/10.19080/NFSIJ.2018.07.555716>
- Kalantar-Zadeh, K., Gutekunst, L., Mehrotra, R., Kovesdy, C.P., Bross, R., Shinaberger, C.S., Noori, N., Hirschberg, R., Benner, D., Nissenson, A.R. and Kopple, J.D. (2010). Understanding sources of dietary phosphorus in the treatment of patients with chronic kidney disease. *Clinical Journal of the American Society of Nephrology*, 5(3), 519-530. <https://doi.org/10.2215/CJN.06080809>
- Kalpanadevi, V. and Mohan, V.R. (2013). Effect of processing on antinutrients and in vitro protein digestibility of the underutilized legume, *Vigna unguiculata* (L.) Walp subsp. *unguiculata*. *LWT - Food Science and Technology*, 51(2), 455-461. <https://doi.org/10.1016/j.lwt.2012.09.030>
- Kaur, M., Singh, N. and Sodhi, N.S. (2005). Physicochemical, cooking, textural and roasting characteristics of chickpea (*Cicer arietinum* L.) cultivars. *Journal of Food Engineering*, 69(4), 511-517. <https://doi.org/10.1016/j.jfoodeng.2004.09.002>
- Khan, K., Moses, S.C., Kumar, A., Kumar, D. and Upadhyay, A. (2017). Physical properties of pigeon pea grains at different moisture content. *International Journal of Pure and Applied Bioscience*, 5(2), 556-562. <https://doi.org/10.18782/2320-7051.2534>
- Khanbarad, S., Joshi, N., Mohapatra, D. and Sutar, R.F. (2014). Effect of moisture content on some selected physical properties of pigeon pea (*Cajanus cajan*). *Journal of Grain Processing and Storage*, 1(1), 6-12.
- Kumari, M. and Jain, S. (2012). Tannins: An antinutrient with positive effects to manage diabetes. *Research Journal of Recent Sciences*, 1(12), 70-73.
- Moussou, N., Ouazib, M., Wanasundara, J., Zaidi, F. and Rubio, L.A. (2019). Nutrients and non-nutrient composition and in vitro starch digestibility of five Algerian legume seed flours. *International Food Research Journal*, 26(4), 1339-1349.
- Narina, S.S., Bhardwaj, H.L., Hamama, A.A., Burke, J.J., Pathak, S.C. and Xu, Y. (2014). Seed Protein and starch qualities of drought tolerant pigeon pea and native tepary beans. *Journal of Agricultural Science*, 6(11), 247-259. <https://doi.org/10.5539/jas.v6n11p247>
- Oboh, G. (2006). Antioxidant properties of some commonly consumed and underutilized tropical legumes. *European Food Research and Technology*, 224(1), 61-65. <https://doi.org/10.1007/s00217-006-0289-x>
- Odeny, D.A. (2007). The potential of pigeon pea (*Cajanus cajan* (L.) Millsp.) in Africa. *Natural Resources Forum*, 31(4), 297-305. <https://doi.org/10.1111/j.1477-8947.2007.00157.x>
- Olagunju, A.I., Omoba, O.S., Enujiugha, V.N. and Aluko, R.E. (2018). Development of value-added nutritious crackers with high antidiabetic properties from blends of Acha (*Digitaria exilis*) and blanched Pigeon pea (*Cajanus cajan*). *Food Science and Nutrition*, 6(7), 1791-1802. <https://doi.org/10.1002/fsn3.748>
- Onwuka, G.I. (2006). Soaking, boiling and antinutritional factors in Pigeon peas (*Cajanus cajan*) and cowpeas (*Vigna unguiculata*). *Journal of Food Processing and Preservation*, 30(5), 616-630. <https://doi.org/10.1111/j.1745-4549.2006.00092.x>
- Oshodi, A.A., Olaofe, O. and Hall, G.M. (1993). Amino acid, fatty acid and mineral composition of pigeon pea (*Cajanus cajan*). *International Journal of Food Sciences and Nutrition*, 43(4), 187-191. <https://doi.org/10.3109/09637489309027541>
- Peters, B.S.E. and Martini, L.A. (2010). Nutritional aspects of the prevention and treatment of osteoporosis. *Arquivos Brasileiros de Endocrinologia and Metabologia*, 54(2), 179-185. <https://doi.org/10.1590/S0004-27302010000200014>
- Popova, A. and Mihaylova, D. (2019). Antinutrients in plant-based Foods: A review. *The Open Biotechnology Journal*, 13(1), 68-76. <https://doi.org/10.2174/1874070701913010068>
- Priska, M., Peni, N., Carvalho, L. and Wae, V.P.S.M. (2020). Effect of drying techniques on nutrition content and gross energy of nuabosi cassava (*Manihot esculenta*) flour. *Biosaintifika*, 12(2), 220-225. <https://doi.org/10.15294/biosaintifika.v12i2.24184>
- Sangronis, E. and Machado, C.J. (2007). Influence of

- germination on the nutritional quality of *Phaseolus vulgaris* and *Cajanus cajan*. *LWT - Food Science and Technology*, 40(1), 116-120. <https://doi.org/10.1016/j.lwt.2005.08.003>
- Seena, S. and Sridhar, K.R. (2005). Physicochemical, functional and cooking properties of under explored legumes, *Canavalia* of the southwest coast of India. *Food Research International*, 38(7), 803-814. <https://doi.org/10.1016/j.foodres.2005.02.007>
- Sharma, S., Agarwal, N. and Verma, P. (2011). Pigeon pea (*Cajanus cajan* L.): A hidden treasure of regime nutrition. *Journal of Functional and Environmental Botany*, 1(2), 91-101. <https://doi.org/10.5958/j.2231-1742.1.2.010>
- Sharma, S., Goyal, R. and Barwal, S. (2013). Domestic processing effects on physicochemical, nutritional and anti-nutritional attributes in soybean (*Glycine max* L. Merrill). *International Food Research Journal*, 20(6), 3203-3209.
- Sinha, K. and Khare, V. (2017). Review on: antinutritional factors in vegetable crops. *The Pharma Innovation Journal*, 6(12), 353-358.
- Soetan, K.O., Olaiya, C.O. and Oyewole, O.E. (2010). The importance of mineral elements for humans, domestic animals and plants: A review. *African Journal of Food Science*, 4(5), 200-222.
- Soris, P.T, Kala, B.K, Mohan, V.R. and Vadivel, V. (2010). The biochemical composition and nutritional potential of three varieties of *Vigna mungo* (L.) Hepper. *Advances in BioResearch*, 1(2), 6-12.
- Souza, R.G.M., Gomes, J.A.C., Naves, M.M.V. and Mota, J.F. (2015). Nuts and legume seeds for cardiovascular risk reduction: Scientific evidence and mechanism of action. *Nutrition Reviews*, 73(6), 335-347. <https://doi.org/10.1093/nutrit/nuu008>
- Stokes, C.S., Lammert, F. and Volmer, D.A. (2018). Analytical methods for quantification of vitamin D and implications for research and clinical practice. *Anticancer Research*, 38(2), 1137-1144.
- Tayade, R., Kulkarni, K.P., Jo, H., Song, J.T. and Lee, J.D. (2019). Insight into the prospects for the improvement of seed starch in legume - A review. *Frontiers in Plant Science*, 10, e01213. <https://doi.org/10.3389/fpls.2019.01213>
- Upadhyaya, H.D., Sharma, S., Reddy, K.N., Saxena, R., Varshney, R.K. and Gowda, C.L.L. (2013). Pigeon pea. In Singh, M., Upadhyaya, H.D. and Bisht I.S. (Eds). *Genetic and Genomic Resources of Grain Legume Improvement*, p. 181-202. London, United Kingdom: Elsevier Inc.
- Urbano, G., López-Jurado, M., Aranda, P., Vidal-Valverde, C., Tenorio, E. and Porres, J. (2000). The role of phytic acid in legumes: Antinutrient or beneficial function? *Journal of Physiology and Biochemistry*, 56(3), 283-294. <https://doi.org/10.1007/BF03179796>
- Wani, I.A., Sogi, D.S., Hamdani, A M., Gani, A., Bhat, N.A. and Shah, A. (2016). Isolation, composition, and physicochemical properties of starch from legumes: A review. *Starch/Stärke*, 68(9-10), 1-12. <https://doi.org/10.1002/star.201600007>
- Wheeler, E. and Ferrel R.E. (1971). A method for phytic acid determination in wheat and wheat fractions. *Cereal Chemistry*, 48, 312-320.
- Williams, H.J. and Edwards, T.G. (1980). Estimation of cyanide with alkaline picrate. *Journal of the Science of Food and Agriculture*, 31(1), 15-22. <https://doi.org/10.1002/jsfa.2740310104>
- Williams, P.C., Nakoul, H. and Singh, K.B. (1983). Relationship between cooking time and some physical characteristics in chickpeas (*Cicer arietinum* L.). *Journal of the Science of Food and Agriculture*, 34(5), 492-496. <https://doi.org/10.1002/jsfa.2740340510>
- Woods, J.T. and Mellon, M.G. (1941). Thiocyanate method for iron, a spectrophotometric study. *Industrial and Engineering Chemistry*, 13(8), 551-554. <https://doi.org/10.1021/i560096a013>
- Yadav, U., Singh, N., Kaur, A. and Thakur, S. (2018). Physico-chemical, hydration, cooking, textural and pasting properties of different adzuki bean (*Vigna angularis*) accessions. *Journal of Food Science and Technology*, 55(2), 802-810. <https://doi.org/10.1007/s13197-017-2994-9>
- Yousif, A.M., Kato, J. and Deeth, H.C. (2003). Effect of storage time and conditions on the seed coat colour of Australian adzuki beans. *Food Australia*, 55(10), 479-484.