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Investigation of the sensory quality, nutritional value and antioxidant capacity of flakes prepared using various pigeon pea-based flours

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Abstract

Pigeon pea (*Cajanus cajan* (L.)) is a potential source of nutritional and antioxidant compounds. Germination proved to improve the nutritional quality and antioxidant capacity of pigeon peas. The previous author's study showed that pigeon pea flour prepared by NaCl elicitation before germination exhibits significantly higher antioxidant capacity and functional properties than that prepared without elicitation or germination. The study aimed to examine the sensory quality, nutrition value, and antioxidant capacity of flakes formulated using non-germinated pigeon pea flour, pigeon pea sprout flour, and NaCl-elicited pigeon pea sprout flour. The potential of the flours to be developed as commercial flakes was also determined using oat-based commercial flakes as a comparator. The NaCl-elicited pigeon pea flour-based flakes showed a higher quality score of both texture and overall qualities than the other pigeon pea flour-based flakes and the commercial ones. Regarding nutritional value, flakes formulated using NaCl-elicited pigeon pea sprout flour also showed better nutritional value, indicated by the lowest fat content and highest soluble, insoluble, and total dietary fiber contents. The highest values of total phenolics content (TPC), Trolox equivalent antioxidant capacity (TEAC), and ferric reducing antioxidant power (FRAP) were also observed in the NaCl-elicited pigeon pea sprout flour-based flakes, even though its DPPH radical scavenging activity was not significantly different to the commercial flakes. These results have significant consequences for developing legume-based flakes with higher levels of dietary fibers and antioxidant potential, and lower fat content.

1. Introduction

Pigeon pea (*Cajanus cajan* (L.)) is one of the most important legumes in tropical and non-tropical regions. Recent evidence suggests that it has several health benefits related to its bioactive compounds (Ariviani *et al*., 2021). A'yuni *et al*. (2022) stated that pigeon pea cultivated in Indonesia has a prospective nutritional value, which is low in fat (1.51-1.61%), high in protein (23.96-24.20%), and potential sources of vitamin A (1,248.83-2,303.6 mg/100 g), potassium (479.66-1,455.51 mg/100 g), phosphate (378.61-411.43 mg/100 g), and calcium (87.21-128.85 mg/100 g). Pigeon peas from the Gunung Kidul region showed significantly higher anti-nutrient compounds than other regions in Indonesia. Germination is one of the most common techniques used to reduce anti-nutrient compounds while improving nutritional quality and antioxidant capacity (Megat *et al*., 2011; Rajendra *et al*., 2019; Ariviani *et al*., 2020; Atudorei *et al*., 2021). Elicitation using 50 mM NaCl prior to germination proved capable of increases in the total flavonoid content, DPPH radical scavenging activity, and FRAP of pigeon pea sprouts (Kristiani *et al*., 2019). The research conducted by Ariviani, Lainuna and Fauza (2020) reported that the NaCl-elicited pigeon pea sprout flour has significantly higher levels of radical scavenging activity, FRAP, and total flavonoid compounds rather than non-elicited pigeon pea sprout flour and non-germinated pigeon pea flour.

Flakes are one of the ready-to-eat breakfast products majorly processed from cereals such as oats, maize,

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wheat, rice, and barley which are generally rich in lysin. Due to the limitation of the threonine and tryptophan amino acid content of cereals, the nutritional traits of flakes could be improved by combination with legume flour (Sattar *et al*., 2021). Recent developments in flakes production involve incorporating nutrient-dense food other than cereals to enhance the nutrients and health-promoting substances (Fasuan *et al*., 2021). Several studies on flakes production developments have been carried out, such as flakes with high-protein soymeal and modified corn starch (Fasuan *et al*., 2021), non-traditional gluten-free flakes (Šťastná *et al*., 2019), flakes from papaya (Attri, 2019), breakfast cereal flakes incorporated with banana pulp and peel (Tay *et al*., 2021), and cereal flakes with adding germinated and non-germinated legumes (Sattar *et al*., 2021).

Several factors that determine the quality of food, among others, are the sensory attribute and nutritional value (Mihafu *et al*., 2020; Imtiyaz *et al*., 2021). Both drive consumers' purchase decisions. One that limits the application of legume flour in food products is the undesirable flavors such as beany and grassy flavors. Steamed paste (Moin-Moin) produced using germinated pigeon pea flour has a higher aroma, taste scores, and antioxidant capacity compared to that prepared using non-germinated pigeon pea flour (Uchegbu *et al*., 2017). Flakes made with germinated legumes produce a higher sensory score and bioactive properties than those made with non-germinated legumes (Sattar *et al*., 2021). To the best of the author's knowledge, the study on the development of flakes from NaCl-elicited and non-elicited pigeon pea sprout flours and pigeon pea flour compared to commercial cereal flakes has not been conducted yet.

This research aimed to evaluate the sensory quality, nutritional value, and antioxidant capacity of flakes prepared with NaCl-elicited and non-elicited pigeon pea sprout flours, pigeon pea flour, and oat-based commercial flakes. Pigeon pea is a nutrient-dense legume which rich in protein, soluble and insoluble dietary fiber, as well as provides higher calcium and manganese in comparison to other commercial legume grains, such as chickpeas and common beans (Miano *et al*., 2020), with total essential amino acids and total essential fatty acids, reach 33.97 mg/100 g and 70.66 mg/100 g respectively (James *et al*., 2020).

2. Materials and methods

The materials used in this study were pigeon pea seeds obtained from the Gunung Kidul region (Province of Daerah Istimewa Yogyakarta, Indonesia), ingredients for flakes preparation purchased from a baking ingredient store in Surakarta (Indonesia), potassium persulfate, ABTS (2,2'Azino-bis (3-ethylbenzothiazoline -6-sulfonic acid) diammonium salt), Trolox ((R)-(+)-6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), DPPH (2,2-diphenyl-1-picrylhydrazyl), and gallic acid were acquired from Sigma Aldrich (St. Louis, MO, USA). Sodium chloride, sodium dihydrogen phosphate dihydrate, disodium hydrogen phosphate dihydrate, methanol, folin-ciocalteau's phenol reagent, sodium carbonate, ascorbic acid, ethanol, potassium ferricyanide, ferric chloride hexahydrate, trichloroacetic acid were obtained from Merck Millipore (Darmstadt, Germany). All reagents used in this study were analytical grade.

2.1 Flour preparation

Flour preparation was carried out according to Ariviani, Lainuna and Fauza (2020). Briefly, pigeon pea seed, NaCl-elicited, or non-elicited pigeon pea sprouts were dehulled, then dried at 80°C using a cabinet dryer (Xingtai XTDQ-101-4, Jiangsu, China) until the moisture content reached 8±2%. The dried materials were milled and sieved through a 60-mesh sieve (Virsair CF812-01, Indonesia). The sprouts were prepared by submerging pigeon pea seeds in distilled water (non-elicited) or 50 mM NaCl solution (elicited) with a ratio of 1:3 w/v for 8 hrs and followed by germination for 48 hours at room temperature. During germination, the seeds are sprayed with distilled water every 12 hrs.

2.2 Preparation of flakes

The preparation of flakes refers to Ariviani *et al*. (2021). Briefly, the pigeon pea-based flour was mixed with banana flour (85:15). The mixed flour was then added with other ingredients, including sugar, salt, butter, eggs and ginger powder. The water was added to the mixture, thus forming a batter. The dough was cooked over low heat in a local crepe mold (AIGLE WK58) until a crispy dough sheet was generated. The sheets were hand crushed to form flakes.

2.3 The sensory quality evaluation

The sensory quality of flakes was evaluated by the multisample difference test (Meilgaard *et al*., 2016) with slight modification, using forty untrained panels. Briefly, the panels were asked to rate whether the pigeon pea-based flakes samples had sensory qualities, including taste, aroma, texture, and overall, were better, equal to, or worse than the reference sample, and also rated the intensities using an intensity scale from very low to very high. Commercial flakes (oat-based flakes) were used as the reference sample (R). The panellists' responses were then transformed to the numeric scale: 1: very strongly worse than R, strongly worse than R, 3: worse than R, 4: slightly worse than R, 5: equal to R, 6: slightly better than R, 7: better than R, 8; strongly better than R, 9: very strongly better than R.

2.4 Nutritional value analysis

The nutritional value of flakes was determined by proximate and dietary fiber analysis. The Proximate analysis includes the measurements of moisture, total minerals, protein, fat and carbohydrate contents (AOAC, 2005). The soluble, insoluble and total dietary fibers were analyzed using the gravimetric enzymatic method AOAC 991.43 (AOAC, 2005).

2.5 Determination of antioxidant potential

The antioxidant potential of flakes was evaluated by measuring the level of total phenolic content (TPC), radical (DPPH• and ABTS•+) scavenging activities and ferric reducing antioxidant power (FRAP). The TPC was analyzed using the Folin-Ciocalteu method described by Singleton *et al*. (1999) and expressed as gallic acid equivalent (mM GAE/100 g sample dry weight). The radical scavenging activities were measured using the DPPH method (Brand-Williams *et al*., 1995) and expressed as gallic acid equivalent activity (µM GAEA/100 g sample dry weight), as well as ABTS•+ free radical method (Re *et al*., 1999) and expressed as trolox equivalent antioxidant capacity (mM TEAC/100 g sample dry weight). FRAP analysis was conducted using the method of Berker *et al*. (2007) and expressed as ascorbic acid equivalent activity (mM AAEA/100 g sample dry weight). Initially, the flakes were extracted using distilled water (1:20 w/v) at 200 rpm, 50°C for 2 hrs using a water bath shaker (SWB 20, Fisher Scientific Haake, Germany). The extract was centrifugated using PLC-05 Centrifuge (Gemmy, Taiwan) at 10000 rpm for 15 mins. The clear supernatant was collected in amber bottles and stored at 10°C until further analysis.

2.6 Statistical analysis

The data were analyzed using the IBM SPSS Statistics 22 program (SPSS Inc., Chicago, USA) with an analysis of variance at a significance level of p-value <0.05 followed by Duncan's Multiple Range Test at a similar significance level. The data has been expressed as means ± standard deviation from three replications.

3. Results and discussion

3.1 Sensory quality of flakes

Previous studies reported that the sensory quality of legumes-based food products, such as pigeon pea steamed paste and cereal flakes from green gram, black gram, and lentil, could be increased by using the legume sprout flours (Uchegbu *et al*., 2017; Sattar *et al*., 2021). The sensory quality, including aroma, taste, texture, and overall qualities of flakes prepared with pigeon pea flour, pigeon pea sprout flour, and NaCl-elicited pigeon pea sprout flour, was presented in Table 1.

The flakes prepared using NaCl-elicited pigeon pea sprout flour have similar quality scores of tastes, texture, and overall, and higher aroma quality than the non-elicited pigeon pea sprout flour-based flakes. It indicated that NaCl-elicitation before germination has no adverse effect on the sensory quality of flakes, even increasing the aroma quality. The pigeon pea flour-based flakes have the lowest taste and aroma qualities, which was in agreement with Uchegbu *et al*. (2017) who revealed that germinated pigeon pea flour produces steamed paste with a higher acceptability score of aroma and taste than that prepared with pigeon pea flour. Lipids oxidation catalyzed by lipoxygenase generates undesirable flavors in legumes (Wang *et al*., 2021). One of the simple and inexpensive ways to reduce lipoxygenase activity is through germination (Kaczmarska *et al*., 2018; Wang *et al*., 2021). Roland *et al*. (2017) reported that germination could reduce undesirable flavors of legumes. Compared to the commercial flakes, both flakes prepared using NaCl-elicited and non-elicited pigeon pea sprout flours exhibited a similar score of aroma and taste qualities and a higher score of texture and overall qualities. Pigeon pea flour-based flakes showed a lower score of aroma quality but equivalent scores for taste, texture, and overall qualities to the commercial flakes.

3.2 Nutritional value of flakes

The nutritional value of the flakes was determined by measurement of proximate (protein, moisture, total mineral, fat and carbohydrate) (Table 2) and dietary fibers including soluble, insoluble, and total dietary fiber (Table 3). Table 2 indicates no significant difference in the moisture, ash, protein, and carbohydrate contents

Table 1. The sensory quality of flakes prepared using pigeon pea flour, non-elicited, and NaCl-elicited pigeon pea sprout flours.

Flakes	Quality score			
	Aroma	Taste	Texture	Overall
Oat-based Commercial flakes	5.40±1.00[bc]	5.40±1.00[ab]	5.10±0.3[a]	5.20±0.41[a]
Pigeon pea flour-based flakes	4.10±0.92[a]	5.00±0.59[a]	5.53±0.94[ab]	5.23±0.63[ab]
Non-elicited pigeon pea sprout flour-based flakes	4.97±0.81[b]	5.50±0.68[b]	5.97±0.76[b]	5.53±0.68[bc]
NaCl-elicited pigeon pea sprout flour-based flakes	5.77±1.01[c]	5.70±1.06[b]	5.83±1.18[b]	5.60±0.68[c]

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

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Table 2. Proximate of flakes prepared using pigeon pea flour, non-elicited, and NaCl-elicited pigeon pea sprout flours.

Flakes	Nutritional Value				
	Moisture content (%wb)	Total minerals content (%db)	Fat content (%db)	Total protein content (%db)	Carbohydrate content (%db)
Oat-based Commercial flakes	4.06±0.19[a]	1.03±0.61[a]	10.98±0.12[d]	15.69±0.32[b]	68.57±0.37[a]
Pigeon pea flour-based flakes	4.02±0.29[a]	0.42±0.02[a]	5.84±0.19[c]	11.57±0.31[a]	77.92±0.48[b]
Non-elicited pigeon pea sprout flour-based flakes	4.07±0.10[a]	0.64±0.04[a]	5.51±0.21[b]	11.51±0.41[a]	78.28±0.73[b]
NaCl-elicited pigeon pea sprout flour-based flakes	4.24±0.22[a]	0.54±0.01[a]	4.86±0.11[a]	12.22±0.52[a]	78.11±0.37[b]

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

Table 3. Soluble, insoluble, and total dietary fiber of flakes prepared using pigeon pea flour, non-elicited and NaCl-elicited pigeon pea sprout flours.

Flakes	Soluble Dietary Fiber (% db)	Insoluble Dietary Fiber (% db)	Total Dietary Fiber (% db)
Oat-based Commercial flakes	2.911*	5.823*	8.734*
Pigeon pea flour-based flakes	3.05±0.05[a]	5.71±0.05[a]	8.77±0.00[a]
Non-elicited pigeon pea sprout flour-based flakes	3.44±0.12[b]	6.13±0.08[b]	9.55±0.05[b]
NaCl-elicited pigeon pea sprout flour-based flakes	7.47±0.02[c]	6.64±0.24[c]	14.12±0.26[c]

*As described in the nutritional facts of the packaging.
Values are presented as mean±SD. Vaues with different superscripts within the same column are statistically significantly different ($p<0.05$).

between the pigeon pea flour-based flakes, pigeon pea sprout flour-based flakes, and NaCl-elicited pigeon pea sprout flour-based flakes. Compared to the commercial flakes, all of the pigeon pea-based flakes showed lower fat and protein as well as higher carbohydrate contents. Among pigeon pea-based flakes, the NaCl-elicited pigeon pea sprout flour-based flakes exhibited the lowest fat level. It indicates that NaCl-elicited pigeon pea sprout flour-based flakes have the potential to be developed as flakes with a reduced fat content that may contribute to more healthy food. Excess fat consumption has correlated to a rise in the risk factors of obesity, hypertension, cancer and heart diseases (Temesgen and Ratta Neguissie, 2015).

Regarding soluble dietary fiber (SDF) content, flakes formulated using pigeon pea sprout flour have a greater level than that prepared using pigeon pea flour. After germination, the SDF from cowpea (*Vigna unguiculata*), dolichos (*Lablab purpureus*), and mucuna (*Stizolobium niveum*) (Benítez *et al*., 2013), kidney bean, mung bean, soybean (Megat *et al*., 2016) increased. Flakes prepared with NaCl-elicited pigeon pea sprout flour have the highest level of SDF. These results indicated that NaCl-elicited pigeon pea sprout flour could potentially be developed as soluble dietary fiber source flakes. SDF exhibits various health benefits such as anti-obesity, antidiabetic, anti-inflammatory, anticancer, and reduces the risk of gastrointestinal diseases by positively regulating the abundance and diversity of gut microbiota and being metabolized into beneficial products (Guan *et al*., 2021).

The insoluble dietary fiber (IDF) content of flakes prepared using pigeon pea flour-based flakes, pigeon pea sprout flour-based flakes, and NaCl-elicited pigeon pea sprout flour-based flakes were higher than the commercial flakes. IDF levels from the lowest to the highest were commercial flakes, pigeon pea flour-based flakes, pigeon pea sprout flour-based flakes, and NaCl-elicited pigeon pea sprout flour-based flakes. The IDF of dark beans (*Phaseolus vulgaris* L.) (Dueñas *et al*., 2016) mucuna, dolichos, cowpea (Benítez *et al*., 2013), kidney bean, mung bean, soybean (Megat *et al*., 2016) increased after germination. Based on the IDF data, it also can be considered that the highly insoluble fiber legumes-based flakes can be produced by germination using the NaCl elicitation technique during legume flour preparation. IDF plays a pivotal role in preventing diabetes by increasing insulin sensitivity (Perry and Ying, 2016). Papandreou *et al*. (2015) reported that IDF has a higher chemoprotective effect than the SDF and proved to have anticancer activity.

Flakes made from pigeon pea sprout flour had a significantly higher total dietary fiber (TDF) content than those made from pigeon pea flour. This is in accordance with previous research which exhibited that the TDF of legumes such as cowpea, dolichos, mucuna, dark bean, kidney bean, mung bean, and soybean increased after germination (Benítez *et al*., 2013; Dueñas *et al*., 2016; Megat *et al*., 2016). The TDF of flakes designed using NaCl-elicited pigeon pea sprout flour was significantly greater than that of other flakes and commercial ones. It indicated that the application of NaCl-elicited cowpea sprout flour could be considered as an alternative

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strategy to produce commercial flakes with the claim to be high in dietary fiber. Barber *et al.* (2020) reported that the health benefits of dietary fiber through metabolic effects, such as an increase in insulin sensitivity, decreased risk of type 2 diabetes, improved glycemic status and lipids profile, loss of body weight and abdominal adipose, gut microflora effect including modification of gut microflora viability and diversity as well as their metabolites, cardiovascular effect, and the localized gastrointestinal effects. The permitted declarations of dietary fiber for products in European declared in European regulations on nutrition and health claims state that a product claiming to be 'high fiber' should contain at least 6 g of fiber per 100 g or at least 3 g of fiber per 100 kcal (European Parliament, Council of the European Union, 2006).

3.2 Antioxidant potential of flakes

The antioxidant potential of the flakes, in terms of the DPPH and ABTS radical scavenging activities (RSA), FRAP, and the total phenolic content (TPC) were presented in Table 4. The DPPH and ABTS RSA of flakes formulated using NaCl-elicited pigeon pea sprout flour were significantly higher than the other pigeon pea-based flakes. This result was related to the RSA of the flours. Ariviani, Lainuna and Fauza (2020) reported that the RSA of NaCl-elicited pigeon pea flour was significantly higher than that of pigeon pea sprout flour as well as pigeon pea flour. Uchegbu and Ishiwu (2016) reported a significant increase in the RSA of pigeon peas after germination. The study by Kristiani *et al*. (2019) proved that germination of pigeon peas using the NaCl elicitation technique could increase the RSA of pigeon pea sprouts up to 134.18%. The DPPH radical scavenging activity of NaCl-elicited pigeon pea sprout flour-based flakes and the commercial oat-based flakes was not significantly different. Meanwhile, the ABTS radical scavenging activity of both flakes prepared with NaCl-elicited pigeon pea sprout flour and pigeon pea sprout flour was significantly greater than the commercial flakes.

The FRAP level of flakes ordered from the lowest to the highest were flakes prepared using pigeon pea flour, commercial flakes, pigeon pea sprout flour-based flakes, and NaCl-elicited pigeon pea sprout flour-based flakes, respectively. It was related to the FRAP of the flours. The NaCl-elicited pigeon pea sprout flour exhibited the highest FRAP, followed by pigeon pea sprout flour, and the lowest FRAP level in pigeon pea flour (Ariviani, Lainuna and Fauza, 2020). The FRAP of pigeon peas could be increased through germination and further increased with NaCl elicitation followed by germination (Kristiani *et al*., 2019). Compared with commercial flakes, both flakes prepared using NaCl-elicited and non-elicited pigeon pea sprout flours have significantly higher levels of FRAP.

The NaCl-elicited pigeon pea sprout flour-based flakes also showed the highest total phenolic content (TPC). NaCl induces salinity stress, stimulating phenolic compound synthesis through proline formation (Ariviani *et al*., 2021). This TPC data was in line with the RSA and FRAP data in Table 4. The antioxidative mechanism of plant phenolic compounds is through reducing ability and via radical scavenging by donating hydrogen atoms or electrons (Craft *et al*., 2012; Zeb, 2020). Compared with commercial cereal, all pigeon pea-based flakes have higher total phenolic content.

4. Conclusion

Both non-elicited and NaCl-elicited pigeon pea sprout flours-based flakes possess better texture and overall qualities and similar quality levels of aroma and taste to commercial flakes. All of the pigeon pea-based flakes exhibited significantly lower fat content and equivalent levels of total minerals and moisture content to the commercial ones. The NaCl-elicited pigeon pea sprouts flour-based flakes showed the lowest fat content. The soluble, insoluble, and total dietary fiber of NaCl-elicited pigeon pea sprout flour-based flakes were the highest among other pigeon pea-based flakes and significantly higher than commercial flakes. The antioxidant capacity which includes DPPH and ABTS radical scavenging activities, FRAP, and TPC of NaCl-elicited pigeon pea sprouts flour-based flakes were also significantly higher than the other pigeon pea-based

Table 4. Antioxidant potential of flakes prepared using pigeon pea flour, non-elicited and NaCl-elicited pigeon pea sprout flours.

Flakes	DPPH radical scavenging activity (μM GAEA/100 g	ABTS•+ radical scavenging activity (mM TEAC/100 g	FRAP (mM AAEA/100g db)	Total Phenolic Content (mM GAE/100 g
Oat-based Commercial flakes	639.33 ± 25.77^{c}	150.04 ± 7.35^{b}	1955.92 ± 158.17^{a}	172.86 ± 7.34^{a}
Pigeon pea flour-based flakes	234.33 ± 19.49^{a}	121.23 ± 12.61^{a}	4123.27 ± 480.19^{b}	301.51 ± 2.52^{b}
Non-elicited pigeon pea sprout flour-based flakes	464.14 ± 39.35^{b}	174.81 ± 5.82^{c}	5264.66 ± 393.80^{c}	458.23 ± 7.87^{c}
NaCl-elicited pigeon pea sprout flour-based flakes	744.93 ± 115.99^{c}	209.73 ± 14.16^{d}	12581.57 ± 801.12^{d}	478.00 ± 3.61^{d}

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

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flakes and the commercial ones. These results suggested an alternative strategy for developing legume-based flakes as commercial products with better nutritional traits and more health-promoting substances indicated by lower fat content and higher levels of dietary fiber and antioxidant potential.

Conflict of interest

The authors declare no conflict of interest.

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