Caraka Tani
Journal of Sustainable Agriculture
ISSN 2613-9456 (Print) 2599-2570 (Online)

Caraka Tani: Journal of Sustainable Agriculture, 40(3), 336-346, 2025
URL: https://jurnal.uns.ac.id/carakatani/article/view/97583
DOI: http://dx.doi.org/10.20961/carakatani.v40i3.97583

Comparative Study of the Nutritional Value, Phytochemicals, and Sensory Quality of Flakes Prepared Using Elicited and Non-Elicited Cowpea Sprout Flours

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Abstract

Germination without and with elicitation using 50 mM NaCl or 250 ppm Na-alginate generated cowpea sprout flours with the levels of protein, total phenolic compounds (TPC), total flavonoid compounds (TFC), radical scavenging activity (RSA), and ferric reducing antioxidant power (FRAP), as well as functional properties that significantly higher than that of cowpea seed flour. Most cereal flakes lack protein content and health-promoting compounds. This study aims to investigate the potential for developing NaCl-elicited, Na-alginate-elicited, and non-elicited cowpea sprout flours for flakes production through a comparative study on the nutritional value (proximate, dietary fibers), phytochemicals (TPC, RSA, FRAP), and sensory quality. Oat-based commercial flake was used as a comparator. The flakes formulated using elicited cowpea sprout flours exhibited significantly lower fat and carbohydrate contents and higher levels of protein, soluble, insoluble, and total dietary fibers than those prepared using non-elicited cowpea sprout flour. The cowpea-based flakes showed more elevated carbohydrate, total, soluble, and insoluble dietary fiber levels and significantly lower fat levels than oat-based commercial flakes. The flakes designed using Na-alginate-elicited cowpea sprout flour have the highest TPC, RSA, and FRAP values. Compared to the commercial ones, flakes prepared with elicited cowpea sprout flours produce better aroma, texture, and overall qualities. These results have significant implications for developing legume-based flakes with lower fat, higher levels of protein, dietary fibers, and phytochemicals, as well as good sensory quality.

Keywords: elicitation; health-promoting compounds; NaCl; Na-alginate; radical scavenging activities

Cite this as: Ariviani, S., Nastiti, G. P., Sholihin, N. H., Fauza, G., & Siswanti. (2025). Comparative Study of the Nutritional Value, Phytochemicals, and Sensory Quality of Flakes Prepared Using Elicited and Non-Elicited Cowpea Sprout Flours. *Caraka Tani: Journal of Sustainable Agriculture*, *40*(3), 336-346. doi: http://dx.doi.org/10.20961/carakatani.v40i3.97583

INTRODUCTION

Cowpeas are reported to be promising sources of nutrients and health-promoting compounds. Nutritionally, cowpea seeds are low in fat (1% dry weight), rich in essential amino acids such as lysine and tryptophan, and approximately two-fold more protein levels than cereals (23 to 32% dry weight). Additionally, their carbohydrate content ranges from 50 to 60% dry weight. Cowpea exerts human health benefits as antidiabetic, anticancer, anti-inflammatory, hypocholesterolemic, and antihypertensive effects, which are attributed to their phenolic compounds and dietary fibers (Jayathilake et al., 2018; Sombié et al., 2018). However, cowpeas are known as underutilized legumes. One of the major limiting factors for the dietary application of cowpea is the presence of anti-nutritional components such as proanthocyanidins, phytic

[*] *Received for publication January 2, 2025*
Accepted after corrections April 24, 2025

acid, and enzyme inhibitors, as well as other compounds including saponins, cyanogenic glucosides, oxalic acid, and 3,4-dihydroxyphenylalanine (Gonçalves et al., 2016).

Germination is a common and straightforward strategy to reduce anti-nutritional compounds while increasing nutritional value, total phenolic content, antioxidant capacity, and the health benefits of legumes (Hung et al., 2020). The germination of cowpea has proven to significantly decrease anti-nutritional compounds, improve protein and total mineral contents, total phenolic and flavonoid compounds (TPC and TFC), and antioxidant activities (Jayathilake et al., 2018), as well as increase soluble, insoluble, and total dietary fibers (Benítez et al., 2013). The bioactive compounds and the bioactivities, including antioxidant and antihypertensive activities of legume sprouts, can be enhanced through elicitation using biotic or abiotic elicitors (Liu et al., 2019). Elicitation triggers desirable secondary metabolite productions; the elicitor type, concentration, and elicitation duration are characteristic of each plant species (Ariviani et al., 2021a). Elicitations with 50 mM NaCl as an abiotic elicitor and 250 ppm Na-alginate as a biotic elicitor have been shown to effectively improve the TPC, TFC, ferric reducing antioxidant power (FRAP), and radical scavenging activity (RSA) of cowpea sprout (Ariviani and Mudalifah, 2023).

Elicitors play roles as plant stress inducers, promoting the biosynthesis of crucial secondary metabolite compounds in the plant's defense system, thus resulting in bioactive compound accumulation. NaCl triggers salinity stress, inducing osmotic stress tolerance via proline formation as an osmolyte. As a carbohydrate-type elicitor, Na-alginate is classified as a "general elicitor" that induces non-specific mechanisms to trigger a plant defense response (Ariviani et al., 2021a). Cowpea sprout flours prepared with NaCl and Na-alginate elicitation, which exhibited the highest levels of RSA, FRAP, TPC, dissolved protein content, and whiteness degree, were generated through air-hot drying at 80 °C for 2 hours (Ariviani et al., 2020a). A previous study reported that germination with and without 250 ppm Na-alginate elicitation increases the antidiabetic capacity, including alpha-amylase and alpha-glucosidase inhibitory activities of pigeon pea seed flour, which was associated with their higher TFC content and antioxidant capacity (Ariviani et al., 2022).

Breakfast flakes are a ready-to-eat product mainly formulated using cereals and developed to meet practicality and convenience needs. However, most flakes lack protein content and other health-beneficial compounds (Fasuan et al., 2021). This limitation can be addressed by incorporating legumes as promising nutrient sources, especially protein and bioactive components (Fasuan et al., 2021; Sattar et al., 2021). Ariviani and Nastiti (2024) reported that flakes prepared using 50 mM NaCl-elicited pigeon pea flour exhibited comparable sensory qualities (similar aroma and taste quality scores and higher texture and overall quality scores), better antioxidant capacities (higher levels of TPC, FRAP, ABTS RSA), and a significantly higher level of soluble, insoluble, and total dietary fibers but lower protein content than commercial flakes. The flour was prepared by soaking the pigeon pea seed in the 50 mM NaCl solution for 8 hours, followed by germination for 48 hours. The seeds were then dehulled and dried at 80 °C for 2 hours, then powdered and sieved through a 60-mesh sieve. Cowpea flour exhibits a more desirable taste and flavor than pigeon pea flour. *Moinmoin* (pudding) and *akara* prepared with cowpea flour have superior flavor and taste qualities compared to those prepared with pigeon pea flour (Fasoyiro et al., 2010). Moreover, cowpea contains significantly higher levels of protein (Jayathilake et al., 2018; Abebe, 2022) and dietary fibers (Abebe and Alemayehu, 2022; Haji et al., 2024) than pigeon pea.

The number of deaths due to non-communicable diseases in 2019 increased by 23% compared to 2000. Although death rates from cancer, cardiovascular diseases, and chronic respiratory diseases have decreased, the number of deaths caused by diabetes has increased (WHO, 2022). One of the risk factors for diabetes is an unhealthy diet. The intake of dietary fiber is inversely related to the risk of diabetes (Yao et al., 2014). Oxidative stress plays a crucial role in the development and pathogenesis of diabetes and its complications. Therefore, the intake of antioxidants is a promising strategy for managing diabetes and its complications (Zhang et al., 2020). The development of ready-to-eat products such as flakes that provide dietary fiber and antioxidant intakes inspires and motivates alternative solutions to health problems, especially those related to diabetes, a cause of death diseases whose numbers continue to increase.

The present study aims to compare the nutritional value, phytochemicals, and sensory quality of flakes prepared using NaCl-elicited, Na-alginate-elicited, and non-elicited cowpea sprout flours. The potential of cowpea sprout flours to be developed as commercial flakes with higher dietary fibers and phytochemicals, reduced fat content, as well as potential antioxidant capacity, was also examined, using oat-based commercial flakes as a comparator. Oats are a source of polyphenols with good antioxidant activities (Orozco-Mena et al., 2014). Oat products show hypoglycemic effects in diabetic rats, related to their high dietary fiber content through mechanisms such as the regulation of fat and glucose metabolism, stimulation of insulin secretion, and protection of pancreas function (Shen et al., 2011). The results of this study have implications for overcoming diabetes as a world health problem through diabetes management by utilizing underutilized legumes in a practical and convenient diet. Underutilized legumes are sustainable contributors to biodiversity conservation and ecological balance due to their nitrogen fixation capacity and the positive effects on soil health. They have also been shown to mitigate the environmental impacts of climate change, further promoting ecological sustainability, which is an essential factor in sustainable agriculture (Odeku et al., 2024).

Several studies have reported the development of flakes using legume flour, such as multigrain flakes made from a mixture of rice, black gram, and flaxseed flours (Rani et al., 2020), rice bean (*Vigna umbellata* (Thunb.)) flour (Bepary et al., 2022), and Desi chickpea (*Cicer arietinum* L.) (David et al., 2025). Sattar et al. (2021) studied breakfast cereal flakes prepared using germinated legume flour, such as lentils (*Lens culinaris*), green gram (*Vigna radiata*), and black gram (*Vigna mungo*) in terms of DPPH RSA, TPC, TFC, and hedonic sensory characteristics. The nutritional and sensory quality, as well as the TPC and antioxidant capacities (TEAC, FRAP, DPPH, and ABTS RSA) of flakes prepared using pigeon peas, pigeon pea sprouts, and NaCl-elicited pigeon pea sprout flours have been investigated in the author's previous study (Ariviani and Nastiti, 2024). However, a comparative study of the nutritional value (proximate, dietary fibers), phytochemicals (TPC, ABTS, and DPPH RSA, FRAP), and sensory quality of flakes prepared using Na-alginate-elicited, NaCl-elicited, and non-elicited cowpea (*Vigna unguiculata*) sprout flours, in comparison to oat-based commercial flakes, has not been conducted yet.

MATERIALS AND METHOD

The materials used in this study were cowpeas obtained from the local market and ingredients for flake formulation purchased from a baking ingredient store in Surakarta (Indonesia). The chemical reagents used were Trolox ((±)-6-Hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid), ABTS (2,2'Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt), potassium persulfate, gallic acid, DPPH (2,2-diphenyl-1-picrylhydrazyl), and sodium alginate were acquired from Sigma Aldrich (St. Louis, MO, USA). Sodium chloride, Folin-Ciocalteu's phenol reagent, sodium carbonate, methanol, disodium hydrogen phosphate dihydrate, and sodium dihydrogen phosphate dihydrate were obtained from Merck Millipore Co. (Darmstadt, Germany).

Cowpea sprout flour preparation

Cowpea sprout flours were prepared according to the method previously described by Ariviani et al. (2020a; 2020b). Cowpea sprouts were prepared by soaking the cowpea seeds in distilled water (non-elicited), 50 mM NaCl (NaCl-elicitation), or 250 ppm Na-alginate (Na-alginate-elicitation) at a ratio of 1:3 w/v for 8 hours. The soaked seeds were then germinated at room temperature for 48 hours. The sprouts were dehulled and dried at a temperature of 80 °C using a cabinet dryer (Xingtai XTDQ-101-4, Jiangsu, China) for 2 hours. The dried sprouts were milled and sieved through a 60-mesh sieve (Virsair CF812-01, Indonesia).

Flakes preparation

The preparation of flakes used a mixture of cowpea sprout and banana flour in an 8:2 w/w ratio, following the method by Ariviani et al. (2021b). Flakes production was conducted according to Ariviani and Nastiti (2024). The flour was combined with other flakes ingredients, followed by the addition of water to form a batter. The batter was cooked in a local crepe mold (AIGLE WK58, Indonesia) over low heat. The crispy sheets produced were crushed into small pieces.

Nutritional value evaluation

The nutritional value analysis was conducted with proximate measurements based on the official method (AOAC, 2005). This included moisture content by the thermogravimetric method (AOAC 935.29), ash content by the dry ashing method (AOAC 950.49), fat content by the Soxhlet extraction method (AOAC 948.22), protein content by the Kjeldahl method (AOAC 950.48), and carbohydrate content calculated using by difference method (AOAC 986.25). Dietary fiber measurements, including soluble, insoluble, and total dietary fibers, were performed using the enzymatic gravimetric method (AOAC 991.43) (AOAC, 2005).

Phytochemical and antioxidant properties

Firstly, flakes prepared using non-elicited, NaCl-elicited, Na-alginate-elicited cowpea sprout flours, and oat-based commercial flakes were extracted using methanol:water (80:20) at a ratio of 1:20 (w/v), as previously described by Ariviani et al. (2020a). The phytochemical evaluation was performed by measuring the TPC using the Folin-Ciocalteu method and expressed as gallic acid equivalent (mM GAE 100 g^{-1} flakes dry weight) (Ariviani et al., 2021b). Additionally, the antioxidant capacity was measured by RSA and FRAP analysis. RSA was determined using the $ABTS^{\cdot +}$ method, expressed as Trolox equivalent antioxidant capacity (mM TEAC 100 g^{-1} flakes dry weight) (Ariviani et al., 2020a), and the DPPH method, expressed as gallic acid equivalent activity (µM GAEA 100 g^{-1} flakes dry weight) (Ariviani et al., 2020b). The FRAP analysis was performed using the method described by Berker et al. (2007) and expressed as ascorbic acid equivalent activity (mM AAEA 100 g^{-1} flakes dry weight).

Sensory quality analysis

The sensory analysis of flakes, including flavor, taste, texture, and overall qualities, was conducted using 40 untrained panelists with the attribute difference test method (Meilgaard et al., 2016). Panelists were asked to compare the quality of each attribute of the flakes samples with a reference sample (oat-based commercial flakes) and assess whether the sample was better, equal to, or worse than the reference. They also determined the intensity of differences using a scale ranging from no difference to a very high difference.

Statistical analysis

The data were presented as means and standard deviations. Statistical analysis was performed using IBM SPSS Statistics 22 software (SPSS Inc., Chicago, USA). Analysis of variance (ANOVA) was conducted at a significance level of p-value < 0.05, followed by Duncan's multiple range test at the same significance level ($p < 0.05$) to identify the differences between treatments.

RESULTS AND DISCUSSION

Nutritional value of flakes

The nutritional value of the flakes was determined by analyzing the proximate (protein, total mineral, moisture, fat, carbohydrate contents) and dietary fiber contents. The results are presented in Table 1. A previous study exhibited that Na-alginate and NaCl-elicited cowpea sprout flours have higher protein and total minerals contents, while lower fat and carbohydrate contents than non-elicited cowpea sprout flour (Ariviani and Mudalifah, 2023). Therefore, it is pivotal to investigate the proximate composition of flakes prepared using non-elicited, Na-alginate-elicited, and NaCl-elicited cowpea sprout flours. Thereby, the potential of the flakes to be developed as higher-protein and lower-fat flakes could be estimated. Excess fat consumption has correlated with increased risk factors for non-communicable diseases (Temesgen and Ratta, 2015). Dietary fibers are an essential nutritional component, yet daily intake in almost all countries in Europe, America, and Asia is still inadequate to meet the recommended daily intake of 25 to 30 g day^{-1} for women and 30 to 35 g day^{-1} for men (Stephen et al., 2017). Information on the dietary fiber content of the flakes is needed to determine their potential as an alternative strategy to overcome inadequate dietary fiber intake.

The moisture content of flakes prepared using non-elicited, Na-alginate-elicited, and NaCl-elicited cowpea sprout flours, as well as oat-based commercial flakes, ranged from 4.12 to 5.13%, indicating that the flakes have a crispy texture. Crispness is one of the pivotal factors determining the quality of flakes, and the moisture content influences this property. The critical moisture content in various breakfast flakes ranges from 8 to 9%. A slight decrease in crispness occurs when the moisture content reaches 7%, with a rapid decline above this level (Sauvagot and Blond, 1991). Flakes formulated using elicited cowpea sprout flour showed higher moisture content than those formulated with non-elicited cowpea sprout flour. It could be related to the higher water absorption capacity (WAC) and water holding capacity (WHC) of the flour. The NaCl-elicited and Na-alginate-elicited sprout flours exhibited higher WAC and WHC than

Table 1. Nutritional value of flakes prepared using elicited and non-elicited cowpea sprout flour

Flakes formulation	Nutritional value							
	Moisture (%)	Total minerals (% dw)	Fat (% dw)	Protein (% dw)	Carbohydrate (% dw)	Dietary fiber (% dw)		
						Soluble	Insoluble	Total
Non-elicited cowpea sprout flour	4.39±0.24^{ab}	0.65±0.02^{a}	5.02±0.05^{a}	10.73±0.65^{a}	83.59±0.61^{b}	3.37±0.08^{a}	6.80±0.03^{a}	9.91±0.10^{a}
NaCl-elicited cowpea sprout flour	4.71±0.29^{b}	0.65±0.03^{a}	5.23±0.02^{b}	11.72±0.20^{b}	82.38±0.17^{a}	3.63±0.04^{b}	6.89±0.19^{b}	11.04±0.14^{b}
Na-alginate-elicited cowpea sprout flour	5.13±0.12^{c}	0.69±0.01^{a}	5.21±0.07^{b}	12.05±0.22^{b}	82.02±0.18^{a}	4.76±0.08^{c}	7.41±0.05^{c}	11.56±0.02^{c}
Commercial flakes	4.12±0.12^{a}	0.76±0.04^{b}	10.43*	14.90*	73.92*	2.98*	5.96*	8.94*

Note: Different superscripts within the same column indicate significantly different ($p < 0.05$), (*) as described in the nutritional facts on the packaging

the non-elicited cowpea sprout flour (Ariviani and Mudalifah, 2023).

All the cowpea flakes samples showed no significant differences in total mineral content, but were lower than commercial flakes. Although both Na-alginate-elicited and NaCl-elicited cowpea sprout flours have significantly higher total mineral content than non-elicited cowpea sprout flour (Ariviani and Mudalifah, 2023), no significant difference was observed in the total mineral content of the prepared flakes. This may be related to the contribution of other ingredients in determining the total mineral content of the flakes.

The flakes formulated using both Na-alginate-elicited and NaCl-elicited cowpea sprout flours displayed a higher fat content than those prepared using non-elicited cowpea sprout flour, reaching 5.21%, 5.23%, and 5.02% dw, respectively. Although Na-alginate-elicited and NaCl-elicited cowpea sprout flours have lower fat content, they exhibited higher oil absorption capacity (OAC) and oil holding capacity (OHC) than non-elicited cowpea sprout flour (Ariviani and Mudalifah, 2023). As a result, the flakes prepared with elicited cowpea sprout flours had a higher fat content. However, the fat content of cowpea flakes was about half of the commercial flakes. Commercial flakes have different ingredients and processes that contribute to the differences in nutritional composition. This result indicated the potential of the elicited and non-elicited cowpea sprout flours to be developed into flakes with lower fat content, which may contribute to healthier diets (Temesgen and Ratta, 2015). According to A Food Labeling Guide by the Food and Drug Administration (FDA), Appendix A, the reduced/less/lower fat food products claim requirement is “at least 25% less fat per RACC than the appropriate reference food” (FDA, 2013). The cowpea sprout flour flakes samples provide 50 to 52% less fat per RACC (30 g) than commercial flakes.

The cowpea flakes samples showed lower protein content than commercial flakes, which ranged from 10.73 to 12.05% dw for the cowpea flakes and reached 14.90% dw for oat-based commercial flakes. Flakes formulated using elicited cowpea sprout flours provided significantly higher protein content than those prepared using non-elicited cowpea sprout flour. This result was related to the higher protein content of the elicited cowpea sprout flour than the non-elicited ones. The enhancement of protein levels during legume germination is related to the mobilization of storage nitrogen. Elicitation during germination induces physiological changes and adjusts to existing conditions that allow the modification of the nutrient composition, including increasing protein levels and reducing the carbohydrate and fat contents (Ariviani and Mudalifah, 2023). The study by Ariviani and Nastiti (2024) reported similar protein content between flakes prepared using elicited and non-elicited pigeon pea flour. This indicates that the impact of elicited legume flour as a flake ingredient on the protein content depends on the type of legume. Research by Devi et al. (2014) stated that the protein content of various commercial breakfast cereals, including flakes, ranges from 8.5 to 11.5%, with an average of 10.1%. Breakfast flakes prepared using maize and a blend of maize-quinoa showed protein content in the range of 7.36 to 9.63% (Abogunrin and Ujiroghene, 2022).

Both flakes formulated with the Na-alginate-elicited and NaCl-elicited cowpea sprout flours had lower carbohydrate content than those prepared using non-elicited cowpea sprout flour, reaching 82.38%, 82.02%, and 83.59% dw, respectively. A study by Ariviani and Mudalifah (2023) reported that NaCl-elicited and Na-alginate-elicited cowpea sprout flours exhibited lower carbohydrate content than non-elicited cowpea sprout flour due to the carbohydrate hydrolysis to fulfill the energy requirements to overcome stress promoted by elicitation. The cowpea flakes samples exhibited significantly higher carbohydrate levels than commercial flakes. The carbohydrate levels of various breakfast flakes range from 67.6 to 86.7% (Jones and Poutanen, 2020). Regular breakfast cereal consumers have a higher carbohydrate intake compared to non-consumers or those who consume less breakfast cereal (Williams, 2014), indicating that breakfast flakes are a significant source of carbohydrate intake.

Dietary fibers are considered a key component in healthy diets (Kaczmarczyk et al., 2012). Dietary fibers exhibits various human health benefits, including improved glycemic status and lipid profiles (mainly soluble fibers), improved insulin sensitivity, reduced risk of diabetes (particularly insoluble fibers), reduced body weight and abdominal adiposity, improved viability and diversity of gut microflora, and reduced risk of cardiovascular disease, cancer, inflammation, and mortality (Barber et al., 2020). Table 1 indicates that all cowpea flake samples have significantly higher soluble, insoluble, and total dietary fiber levels than the oat-based commercial flakes.

Germination increases the soluble, insoluble, and total dietary fibers of cowpea seeds due to the synthesis of new polysaccharides during germination, which causes changes in the cell wall matrix (Benítez et al., 2013). Elicitation using biotic and abiotic elicitors effectively increases the bioactive compounds of sprouts, including dietary fibers (Liu et al., 2019; Thakur et al., 2019). Flakes formulated using Na-alginate-elicited cowpea sprout flour exhibited the highest levels of soluble, insoluble, and total dietary fibers, followed by flakes prepared using NaCl-elicited cowpea sprout flour, with the lowest levels observed in those prepared using non-elicited cowpea sprout flour. Na-alginate and NaCl elicitation before germination could be an alternative technique for improving the dietary fiber contents of leguminous flour, potentially being applied and developed as commercial flakes high in dietary fiber to help overcome inadequate dietary fiber daily intakes.

According to European regulations on nutrition and health claims (Annex of Regulation, 2006), a claim that a food is high in fiber should contain at least 6 g of fiber per 100 g or at least 3 g of fiber per 100 kcal. Each serving size (35 g) of flakes made from non-elicited cowpea sprout flour, NaCl-elicited, and Na-alginate-elicited cowpea sprout flours meets the dietary fiber daily intake requirements of 12.4%, 13.8%, and 14.5%, respectively, according to the recommended daily intake by FDA, which is 28 g (FDA, 2020).

Phytochemicals and antioxidant properties: TPC, ABTS and DPPH RSA, and FRAP

The phytochemicals and antioxidant capacities of flakes formulated using non-elicited, NaCl-elicited, and Na-alginate-elicited cowpea sprout flours compared to oat-based commercial flakes are presented in Table 2. Flakes prepared using both non-elicited and elicited cowpea sprout flours give higher TPC than commercial flakes. The TPC of flakes prepared using non-elicited cowpea sprout flour was significantly lower than those prepared with elicited cowpea sprout flours. Elicitation has been shown to increase the TPC of several legume sprouts (Liu et al., 2019; Thakur et al., 2019) through two mechanisms. First, it triggers the gene expression of the phenylalanine ammonia-lyase (PAL) enzyme, a critical enzyme in phenolic compound synthesis. Second, elicitors can loosen cell walls, thus

Table 2. Phytochemicals and antioxidant properties (TPC, ABTS·+ and DPPH· RSA, and FRAP) of flakes designed with elicited and non-elicited cowpea sprout flours

Flakes formulation	Total phenolic contents (mM GAE 100 g^{-1} flakes dry weight)	ABTS·+ RSA (TEAC) (mM TE 100 g^{-1} flakes dry weight)	DPPH· RSA (GAEA) (µM GAE 100 g^{-1} flakes dry weight)	FRAP (AAEA) (mM AAE 100 g^{-1} flakes dry weight)
Non-elicited cowpea sprout flour	1,361.09±62.14^{b}	7,585.32±272.88^{b}	818.40±46.62^{b}	23,660.33±713.60^{b}
NaCl-elicited cowpea sprout flour	1,612.94±69.05^{c}	9,342.79±290.18^{c}	953.66±30.62^{c}	30,501.97±1,253.06^{c}
Na-alginate-elicited cowpea sprout flour	1,848.52±90.96^{d}	11,325.52±294.83^{d}	1,266.31±12.95^{d}	39,378.37±1,412.81^{d}
Commercial flakes	597.79±35.59^{a}	3,871.39±181.09^{a}	640.21±34.40^{a}	3,265.64±522.48^{a}

Note: Different superscripts within the same column mean significant differences ($p < 0.05$)

releasing cell wall-bound phenolic compounds (Liu et al., 2019).

Na-alginate-elicited cowpea sprout flour produces flakes with significantly higher TPC than NaCl-elicited cowpea sprout flour, suggesting that Na-alginate-elicited legume sprout flour could be considered a more promising ingredient for developing flakes with higher bioactive compounds. Phenolic compounds of cowpea, such as phenolic acids, flavonols, flavan-3-ols, and anthocyanins, offer various health benefits, such as antidiabetic, anti-inflammatory, anticancer, antihypertensive, and cardioprotective properties (Awika and Duodu, 2017). Na-alginate-elicited cowpea sprout flour showed higher TPC levels than NaCl-elicited cowpea flour due to the higher stress induced by Na-alginate elicitation than NaCl elicitation. The higher stress level condition promotes a higher defense response by secondary metabolite production, including higher production of phenolic compounds (Ariviani and Mudalifah, 2023).

The DPPH· and ABTS·+ RSA and the FRAP of flakes formulated using non-elicited cowpea sprout flours were significantly lower than those prepared using elicited cowpea sprout flours but considerably higher than the commercial flakes (Table 2). These results align with previous studies that reported elicitation improves DPPH· RSA, ABTS·+ RSA (TEAC), and FRAP in legume sprouts (Ariviani et al., 2020a; Ariviani and Mudalifah, 2023). Elicitation leads to oxidative stress, thus stimulating the antioxidative defense system through the induction of antioxidant biosynthesis (Swieca, 2015). The higher RSA and FRAP values are consistent with the TPC levels of the flakes (Table 2). Plant phenolic compounds display antioxidative properties through radical scavenging by donating hydrogen atoms or electrons and reducing power (Gulcin, 2020). The TPC of several legumes was positively correlated to the ABTS·+ RSA (TEAC) and the FRAP (Ariviani et al., 2021a).

Sensory quality of flakes

The sensory qualities of flakes, including flavor, taste, texture, and overall quality, are presented in Table 3. The color quality was not evaluated, as it was considered that the color of the flakes could be manipulated by adding food coloring agents or other ingredients. All the cowpea flakes samples exerted similar quality scores of the flavor, texture, and overall quality, which were significantly ($p < 0.05$) higher than those of commercial flakes. However, all flakes samples produced equivalent taste quality scores. These results indicate that germination may improve the flavor quality of cowpea by reducing undesirable flavors naturally present in legumes. Like other legumes, cowpea has unpleasant flavors, such as beany and green flavors, resulting from lipid oxidation by endogenous lipoxygenase in legumes (Kaczmarska et al., 2018; Wang et al., 2021). Germination has been shown to reduce undesirable flavors in legumes by decreasing the lipoxygenase activity (Wang et al., 2021). According to the sensory qualities, the non-elicited, Na-alginate-elicited, and NaCl-elicited

Table 3. Sensory quality of flakes formulated using elicited and non-elicited cowpea sprout flour

Flakes formulation	Sensory quality score (*)			
	Flavor	Taste	Texture	Overall quality
Non-elicited cowpea sprout flour	5.50±0.82[b]	5.03±0.89[a]	5.47±0.73[b]	5.23±0.68[b]
NaCl-elicited cowpea sprout flour	5.47±0.94[b]	5.47±0.82[a]	5.37±0.93[b]	5.37±0.81[b]
Na-alginate-elicited cowpea sprout flour	5.37±0.93[b]	5.30±0.99[a]	5.30±0.88[b]	5.33±0.80[b]
Commercial flakes	4.73±0.69[a]	5.00±0.98[a]	4.60±0.62[a]	4.80±0.61[a]

Note: (*) Score 4 = Slightly worse than R, 5 = Equal to R, 6 = Slightly better than R. R is oat-based commercial flakes. Different superscripts within the same column indicate significantly different ($p < 0.05$)

cowpea sprout flours have the potential to be developed into commercial flakes, as indicated by their higher levels of flavor, taste, and overall quality scores compared to oat-based flakes, which are already established in the market.

CONCLUSIONS

Flakes prepared using NaCl-elicited and Na-alginate-elicited cowpea sprout flours are proven to be a "high fiber" product with significantly higher total, soluble, and insoluble dietary fibers than the oat-based commercial flakes. These flakes displayed lower fat content, i.e., about half of the commercial ones. Moreover, the flakes also exhibited the potential source of phytochemicals indicated by the RSA, FRAP, and TPC, which were three times higher than those of commercial flakes. The flakes also showed comparable sensory quality scores with the oat-based commercial flakes. These indicate that NaCl-elicited and Na-alginate-elicited cowpea sprout flours potentially developed as commercial functional flake products with high levels of dietary fibers, antioxidant capacity, and lower fat content. The results of this study have implications for the utilization of underutilized legumes as ready-to-eat food products with nutrition and health claims.

ACKNOWLEDGEMENT

This research was financially supported by the Non-State Budget Funding Research (Non-APBN) Grant of the Universitas Sebelas Maret in 2023 through the Applied Excellence Research (PUT) scheme with contract number 228/UN27.22/PT.01.03/2023.

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