

Chemical and physical properties of canna (*Canna edulis*) and jack bean (*Canavalia ensiformis*)-based composite flours

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Article history:

Received: 1 May 2021

Received in revised form: 9 June 2021

Accepted: 23 August 2021

Available Online: 17 April 2022

Keywords:

Canna,
Jack bean,
Composite flours,
Chemical,
Physical

DOI:

[https://doi.org/10.26656/fr.2017.6\(2\).292](https://doi.org/10.26656/fr.2017.6(2).292)

Abstract

Poor dietary patterns and unhealthy lifestyles are common risk factors for non-communicable ailments, the leading causes of global death rates. Therefore, improvement of diet quality is necessary and a gluten-free diet would be the right option. This diet is not solely for patients with gluten-related diseases but has also become a trend for consumers, due to the health benefits of gluten avoidance. Underutilized food crops, including tubers and legumes, are potential raw materials for producing gluten-free food. In this study, the physicochemical properties of canna (*Canna edulis*) and jack bean (*Canavalia ensiformis*)-based composite flours were investigated. The composite flours were produced using canna flour to jack bean flour ratios of F1 (85:15), F2 (70:30), and F3 (55:45). Based on the experiment's result, an increase in jack bean flour proportion significantly ($p < 0.05$) increased the composite flour's protein content, lightness, and resistant starch content of composite flours, but significantly ($p < 0.05$) reduced carbohydrate content, oil holding capacity, and swelling power. According to the scoring test result, F2 (70:30) has the highest result and was selected as the best formula. Thus, a combination of canna and jack bean flours indicated promising properties of gluten-free flour for functional food alternative resources.

1. Introduction

Currently, non-communicable diseases are the major cause of death across the globe, amounting to about 41 million or 71% of deaths in 2016. In Indonesia, these diseases were responsible for 1.9 million or 73% of deaths in 2016 (WHO, 2018). Cancers, cardiovascular diseases, diabetes, and chronic respiratory diseases are the four main non-communicable diseases associated with behavioural risk factors (physical inactivity, harmful use of alcohol, tobacco use and salt/sodium intake) and metabolic risk factors (raised blood pressure and glucose, as well as obesity). Furthermore, non-communicable diseases are not only threatening the older population but also increase the proportion of premature adult deaths (mortality in people between 30 and 69 years) (WHO, 2018). Based on the risk factors, non-communicable diseases are directly linked to dietary patterns. Therefore, improving diet quality and reducing malnutrition are convenient strategies to overcome this problem (UNSCN, 2018). A gluten-free diet is a potential approach for non-communicable disease prevention and treatment, especially diabetes. Dietary gluten possibly contributes to the development of diabetes, and this affects the inflammatory milieu as well

as induces beta-cell stress. Gliadin, one of the gluten peptides type, especially α -gliadin, is the most immunogenic gluten peptide and has the ability to cross the intestinal barrier, which increases intestinal permeability and inflammatory milieu. Then, after entering the pancreas, the gluten peptides may activate receptor TLR4 associated with insulin resistance and beta-cell dysfunction. Thus, a gluten-free diet evidently reduced type 1 diabetes during pregnancy and obesity, as well as type 2 diabetes (Haupt-Jorgensen *et al.*, 2018). This diet is well recommended for patients with gluten-related diseases patient, and the trend in gluten-free food consumption has been growing due to multiple factors, including the clinical benefits of gluten avoidance (Niland and Cash, 2018). However, previous studies reported that commercial gluten-free food products contained low protein and fibres, and higher contents of carbohydrates, saturated fats, and salts compared to their gluten-containing counterparts (Melini and Melini, 2019; Myhrstad *et al.*, 2021). Thus, the use of underutilized crops, for instance, tubers and legumes are an alternative ingredient for gluten-free food and have the ability to improve protein, micronutrients, as well as functional properties (Melini and Melini, 2019). This study,

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therefore, investigates gluten-free flour consisting of canna tuber and jack bean flours.

Edible canna (*Canna edulis*) originated in South America (Andes region) and was spread by the Portuguese to Asian, Australian, and African regions, including Indonesia. In Indonesia, *Canna edulis* is well known as *ganyong*, and commonly exist in West Java (Ciamis, Majalengka, Karawang, Sumedang, Cianjur, Subang, and Garut), East Java (Pasuruan and Malang), and Central Java (Purworejo, Klaten, and Wonosobo). Edible canna is one perennial plant with the ability to adapt to the environment, as well as a moderately high crop growth rate, without intensive improvement, and is categorized into red or white canna, in terms of root colour (Imai, 2008; Suhartini and Hadiatmi, 2010). The plant is rich in carbohydrates, starch, minerals, as well as phenolic compounds, and white canna starch consists of 6.49% moisture, 0.37% ash, 0.45% protein, 0.67% fat, as well as 98.53% carbohydrate (Carolina and Ilmi, 2016). Furthermore, edible canna contains polyphenolic compounds, indicating high radical scavenging activity and attributed with antioxidant activity, and the plant has been proven to reduce colorectal carcinogenesis through chemopreventive effect, due to the high calcium and dietary fibre content, acting as an anti-proliferative agent (Mishra et al., 2012; Burhannudin et al., 2018). In addition, *Canna edulis* type 3 resistant starch also exhibited an anti-diabetic effect (Zhang et al., 2020). Canna flour and starch were applicable for manufacturing various food products, due to their nutritional quality and functional properties. Several applications of edible canna flour or starch, have also been conducted, for instance, as a substituent for wheat flour (Aprianita et al., 2014), noodles (Santacruz et al., 2009; Wandee et al., 2015), gluten-free cookies (Nugraheni et al., 2019), composite flours (Praseptiangga et al., 2018), and food bar (Welli et al., 2020). Thus, edible canna is a potential source of functional food to encourage food security and a healthy diet.

Meanwhile, jack bean (*Canavalia ensiformis*), commonly known as *koro pedang* in Indonesia, originated from South America and was scattered and cultivated in tropical as well as subtropical regions (Vadivel et al., 2012). Jack bean is widely grown in South Asia and Southeast Asia, including India, Sri Lanka, Myanmar, and Indo-China (Wahjuningsih and WyatiSaddewisasi, 2013). Furthermore, legumes, including jack bean, are potent plants with high resistance to diseases, pests, and adverse environmental conditions (Sridhar and Seenaa, 2006). *Canavalia ensiformis* is relatively easy to grow in arid to semi-arid regions, marginal soils, and produces high yields in regions with high temperature, low altitude, and high

relative humidity. However, different environmental conditions and locations determine the seed protein's quality and quantity (Doss et al., 2011). Despite the benefits, the plant contains anti-nutrient compounds, including concanavalin A, saponin, cyanogenic glycosides, alkaloids, and trypsin inhibitors, restricting the seed's utilization (Agbede and Aletor, 2005). However, appropriate processing techniques, including autoclaving, cooking and soaking, help to reduce or eliminate trypsin inhibitor activity as well as 3,4-dihydroxy-L-phenylalanine (L-Dopa) (Doss et al., 2011). This plant is also an inexpensive legume and a rich source of protein as well as bioactive compounds. The proximate composition of raw jack comprises 8.41% moisture, 4.48% ash, 4.20% fat, 29.8% protein, 50.8% carbohydrate, and 7.37% crude fibre (Doss et al., 2011). Also, the plant's methanolic extract contains acceptable levels of free phenolics, indicating the presence of antioxidants and type 2 diabetes-related enzyme inhibitory properties (Vadivel et al., 2012). Meanwhile, concanavalin A (ConA) of jack bean lectin indicated anti-proliferative activity in human leukaemia cells and is promising for cancer treatment (Faheina-Martins et al., 2012). However, the plant has a peculiar nature, long cooking time, and beany flavour, limiting further development. A previous study, therefore, suggested steaming jack bean seed for 45 minutes to help retain adequate nutrients, save energy, and minimize the time of cooking (Akande et al., 2013). Also, the substitution of jack bean flour in food products, including composite flours (Affandi et al., 2017), bread (Ugwuona and Suwaba, 2013), breakfast products (Hapsari et al., 2019), and sweet bread (Ariyantoro et al., 2020), successfully improved the nutrient quality and functional properties of the food products. Currently, there are no known records of canna and jack bean-based composite flour manufacture. Hence, this study is aimed to investigate the flours' chemical and physical properties, for further utilization of tubers and legumes, in the development of functional food ingredients.

2. Materials and methods

2.1 Materials

Canna tuber (*ganyong*) was procured from a local farmer within Glintang Village, Sambu, Boyolali, Central Java, Indonesia, while jack bean was obtained from "Yayasan Gita Pertiwi", Surakarta, Central Java, Indonesia. All the chemicals used in this study were of analytical grade, including benzene, H₂SO₄ (Merck, Germany), Ag₂O₂, K₂SO₄, NaOH-Na₃SO₄, boric acid, MR-MB indicator, HCl (Merck, Germany), HClO₄, NaOH (Merck, Germany), Cu reagent, Nelson reagent, ethanol, acetate acid, iodine, KCl-HCl buffer, pepsin enzyme (Merck, Germany), trismaleate buffer, KOH, α-

amylase enzyme (Sigma-Aldrich, USA), sodium acetate buffer, amyloglucosidase enzyme, DPPH reagent (Merck, Germany), sodium carbonate, Folin-Ciocalteu reagent (Merck, Germany), phosphate buffer, glucose oxidase-peroxidase reagent/ GO-POD (DiaSys, Germany), arsenomolybdate reagent, pure amylose, pure phenol, methanol.

2.2 Preparation of composite flours

This was performed by combining canna tuber and jack bean flours. The canna tuber was sorted, peeled, washed, thinly sliced (2 mm) and dried at 60°C, for 20 hrs, in a cabinet dryer. Subsequently, the dried samples were ground with a grinding mill and sieved (80 mesh) to obtain a fine powder. Meanwhile, the jack beans were subjected to pre-treatment to reduce HCN levels. This was carried out by immersing the beans in the water for three days, and replacing the water every 12 hrs, as stated in previous studies (Faheina-Martins *et al.*, 2012; Praseptiangga *et al.*, 2018). The rinsed beans were then boiled for 20 mins, peeled, chopped, and dried for 10 hrs, at 60°C, in a cabinet dryer. This was followed by grinding and sieving (80 mesh) of the samples, to obtain jack bean flour (Faheina-Martins *et al.*, 2012; Praseptiangga *et al.*, 2018). Finally, canna tuber flour and jack bean flour were proportionally weighted and well-mixed in ratios of 85:15 (F1), 70:30 (F2), and 55:45 (F3), until a homogenous mixture was obtained (Faheina-Martins *et al.*, 2012; Praseptiangga *et al.*, 2018).

2.3 Physical characteristics

The composite flours' physical characteristics were determined with the following method of analysis. Flour yield was determined by calculating the percentage of the ratio between flour's weight and raw materials' weight (AOAC, 2005). Then, flour colour was analyzed by using a chromameter (Konica Minolta CR-400) based on CIE-L*a*b* system (Hutchings, 2017). Subsequently, flour's water absorption capacity was determined by filtering method with filter paper, while the oil holding capacity of the composite flours was determined by using palm oil with centrifuge method and described by Sosulski *et al.* (1976). Moreover, the flour's water holding capacity and swelling power were determined by the centrifuge method and described by Chau and Huang (2003) and Leach *et al.* (1959), respectively.

2.4 Proximate analysis

The proximate composition of the composite flours was analyzed according to AOAC standard method (AOAC, 2005). Moisture content using the thermogravimetric method, ash content using the incineration method, fat content using the Soxhlet extraction method, protein content using micro Kjeldahl

method, and carbohydrate content using by difference.

2.5 Determination of starch, amylose, and amylopectin contents

Total starch content was determined enzymatically according to Mir *et al.* (2013). The sample (100 mg) was added with thermo-stable pancreatic α -amylase and amyloglucosidase enzymes and then incubated in a shaking water bath (37°C, 16 hrs). The two enzymes were solubilized in the non-resistant starch part of the sample and the end of the reaction was assigned with the increment of an equal volume of aqueous ethanol. Then, the resistant starch was obtained by centrifugation and decantation. Afterwards, the resistant starch was mixed with 2 M KOH and placed in a shaking water bath for 20 min. Then, the mixture was added with 1.2 M sodium acetate buffer, pH 3.8, and amyloglucosidase enzyme to hydrolyze the starch to glucose. Subsequently, the absorbance of the released glucose was determined using glucose oxidase-peroxidase reagent (GO-POD) at 510 nm. Then, the total starch content was calculated as the amount of resistant starch and non-resistant starch.

Amylose content was analyzed using the colourimetric method described by Mir *et al.* (2013). Briefly, the sample was diluted with 1 ml ethanol and 9 ml of 2 M NaOH in a volumetric flask. Then, the solution was added with the iodine solution and incubated at room temperature for 10 mins. Afterwards, the absorbance of the solution was measured at 620 nm and the amylose content was determined using a standard curve, while the amylopectin content was calculated by the difference between total starch content and amylose content.

2.6 Determination of resistant starch content

The resistant starch content was measured using the method described by Goni *et al.* (1996) with modifications. Briefly, the sample was put into a centrifuge tube and mixed with 10 mL buffer KCl-HCl, pH 1.5. Then, 0.2 mL of pepsin solution (1 g pepsin/10 mL buffer KCl-HCl) was added and incubated at 40°C for 60 mins in a shaking water bath. The sample was taken out from the water bath, cooled down to room temperature, and followed by adding 9 mL of 0.1 M Trismaleate buffer, pH 6.9, and 1 mL of the α -amylase solution. Afterwards, the sample was incubated in a shaking water bath (40°C, 16 hrs). Subsequently, the tested sample was centrifuged (15 mins, 3000 rpm) and its supernatant was disposed of. While the residue was added with 3 mL distilled water and 3 mL of 4 M KOH, then incubated at room temperature for 30 mins with constant stirring. Moreover, the sample was added with 5.5 mL of 2 M HCl, 3 mL of 0.4 M sodium acetate

buffer (pH 4.75), 80 μ L of amyloglucosidase enzyme, and incubated in the shaking water bath (60°C, 45 mins). Then, the sample was centrifuged (15 mins, 3000 rpm) and the supernatant was collected, while the residue was washed with 10 mL of distilled water and centrifuged again and the supernatant was combined with previously yielded. The supernatants were diluted with distilled water to make a 50 mL solution and used for determining glucose concentration.

Glucose concentration was measured using the Nelson-Somogyi method. Before the analysis, the standard curve of standard glucose solution (10 mg anhydrous glucose/ 100 mL distilled water) was made and serially diluted with various concentrations. Then, 1 mL of the solution was placed in a tube, added with 1 mL of Nelson reagent, and heated with boiling water for 20 mins, then cooled down to 25°C. The solution was added and well mixed with 1 mL arsenomolybdate reagent and 7 mL of distilled water. Later, the absorbance of the solution was measured at 500 nm and used for determining standard curves by plotting known glucose concentration and the absorbance values. Moreover, the glucose concentration of obtained supernatant of the sample was determined using a similar procedure. The resistant starch content of the sample was analyzed by converting the glucose concentration with a conversion factor (0.9) and calculated with the following equation:

$$\text{Glucose concentration (mg)} = \frac{\text{standard glucose } \left(\frac{\text{mg}}{\text{mL}}\right) \times \text{sample volume (mL)} \times \text{dilution factor} \times 1 \text{ mg}}{\text{sample weight (mg)}} \quad (1)$$

$$\text{Resistant starch content} = \text{glucose concentration (mg)} \times 0.9 \quad (2)$$

2.7 Determination of dietary fibre content

Dietary fibre content was determined using the enzymatic-gravimetric method described by Asp *et al.* (1983). The sample (1 g) was placed in an Erlenmeyer and added with 25 mL of 0.1 M phosphate buffer, pH 6, then mixed with 0.1 mL α -amylase enzyme. The mixture was incubated in a shaking water bath (80°C, 15 mins). Afterwards, the sample was cooled down and added with 20 mL distilled water and HCl or NaOH solution to reach pH 1.5. Then, 0.1 g pepsin enzyme was added and the mixture was incubated again with the shaking water bath (40°C, 60 mins). Subsequently, 20 mL of distilled water was added and adjusted the pH to 6.8 and incubated again (40°C, 60 mins). The pH of the sample was adjusted to 4.5, and then the sample was filtered with the vacuum pump and washed twice with 10 mL of distilled water. The residue or insoluble dietary fibre (IDF) part of the sample was washed twice with 10 mL of 90% ethanol and 10 mL acetone. Moreover, ash content (a) and moisture content (m) of the sample were determined using a furnace and an oven until constant weight, respectively. While the sample filtrate as soluble

dietary fibre (SDF) was rinsed with 100 mL distilled water and added with 400 mL of 90% ethanol (60°C) and precipitate as the result. The precipitate was vacuum filtered and twice rinsed with 10 mL of 78% ethanol, 10 mL of 95% ethanol, and 10 mL of acetone. Furthermore, ash content (a) and moisture content (m) of the sample were determined using a furnace and an oven until constant weight, respectively. While the blank was determined using the similar procedure and the dietary fiber content was calculated using the following equation:

$$\text{IDF} = \left(\frac{d_1 - a_1 - b_1}{w} \right) \times 100\% \quad (3)$$

$$\text{SDF} = \left(\frac{d_2 - a_2 - b_2}{w} \right) \times 100\% \quad (4)$$

$$\text{Total fibre content} = \text{IDF} + \text{SDF} \quad (5)$$

Where $d_{1,2}$ is sample weight after drying, $a_{1,2}$ is sample weight after ashing, $b_{1,2}$ is the difference between sample weight and free blank, and w is initial sample weight.

2.8 Determination of antioxidant activity

The antioxidant activity measurement was performed with the DPPH method described by Molyneux (2004) with modifications. Briefly, the flour sample (50 mg) was placed in a centrifuge tube containing ethanol/distilled water solution (70:30), as a solvent agent, and centrifuged at 150 rpm for 10 mins. Then, the sample was incubated in the dark for 12 hrs to collect the supernatant. The supernatant and residue were separated, and then the residue was extracted by adding a 5 mL solvent solution. The sample extract (supernatant and extraction result) was incubated at 4°C in the dark condition and followed by mixing the sample (1 mL) with 1 mL DPPH solution and vortex for 1 min. Moreover, the sample was incubated at room temperature in the dark for 30 mins. Then, the absorbance (Abs) of the sample extract was measured at 517 nm with ethanol 70% as the control sample (blank). The antioxidant activity was measured with the following equation:

$$\text{Antioxidant activity (\%)} = \left[\frac{1 - \text{Abs}_{\text{sample}}}{\text{Abs}_{\text{blank}}} \right] \times 100\% \quad (6)$$

2.9 Determination of total phenolic content

Total phenolic content was determined using the Folin-Ciocalteu method reported by (Rusyidi and Azrina, 2012) with modifications. About 0.5 mL of liquid-phase of the sample (1:10 w/v) was mixed with 5 mL Folin-Ciocalteu reagent (1:10 v/v, diluted with distilled water) and 4 mL sodium carbonate solution. Then, the sample was vortex and incubated for 15 min in the dark. The total phenolic content was measured using a spectrophotometer (Thermo Scientific SPECTRONIC 200) and the absorbance was measured at 765 nm.

2.10 Data analysis

Data obtained were statistically analyzed using the One-way Analysis of Variances (ANOVA) method, with SPSS version 16.0. Subsequently, the differences between the results were further analyzed using Duncan Multiple Range Test (DMRT), for results with a 5% significance level ($p < 0.05$). Meanwhile, the composite flour formula was determined using the non-dimensional scaling method (De Garmo and Sullivan, 1984). Initially, the best and the worst values of each parameter were determined based on the result of physicochemical characteristics of composite flour. Then, the variable weight (VW) of each parameter was determined from 0 to 1 according to the effect of the parameter on composite flours quality. The variable weight of all parameters was 1, due to the equal effect of the parameter on composite flours quality. Subsequently, normalization weight (NW), non-dimensional value (NV), and parameter score were calculated using the following equation:

$$NW = \frac{vw}{\sum vw} \quad (7)$$

$$NV = \frac{\text{value} - \text{worst value}}{\text{best value} - \text{worst value}} \quad (8)$$

$$\text{Score} = NW \times NV \quad (9)$$

The score of each parameter was determined and the

highest score was defined as the best composite flours formula.

3. Results and discussion

3.1 Chemical properties of canna flour and jack bean flour

According to Table 1, the proximate composition of canna flour is 5.71% moisture, 4.44% ash, 0.15% fat, 3.02% protein, and 86.66% carbohydrate, while jack bean flour consists of 7.36% moisture, 1.26% ash, 4.46% fat, 19.80% protein, and 67.12% carbohydrate. This result was compared with previous studies, stating jack bean flour consists of 7.00 to 10.30% moisture, 2.43 to 4.50% ash, 3.76 to 5.38% fat, 21.00 to 32.4% protein, and 50.60 to 58.00% carbohydrate (Vadivel and Janardhanan, 2001; Acevedo *et al.*, 2013; Akande *et al.*, 2013). In summary, canna flour has a high carbohydrate and low protein content, therefore, the substitution of jack bean flour potentially improved the composite flour's nutritive value. Table 1 shows the results of starch, amylose, and amylopectin analysis of canna flour found to have a percentage value of 66.22%, 37.30%, and 28.92%, respectively. These results are slightly lower, compared to a study by Carolina *et al.* (2016), reporting canna starch to contain 86.59% starch, 25.50% amylose, and 61.50% amylopectin (Carolina and Ilmi,

Table 1. Chemical and physical properties of canna flour and jack bean flour

Parameter	Canna flour	Jack bean flour
Yield (%)	12.53±0.05	41.56±0.33
Color		
L*	74.96±0.02	88.65±0.02
a*	2.80±0.01	-0.80±0.02
b*	16.67±0.04	15.10±0.02
Proximate		
Moisture	5.71±0.03	7.36±0.03
Ash	4.44±0.01	1.26±0.01
Fat	0.15±0.00	4.46±0.00
Protein	3.02±0.03	19.80±0.18
Carbohydrate	86.66±0.00	67.12±0.21
Starch	66.22±0.02	54.03±0.03
Amylose	37.30±0.03	22.88±0.02
Amylopectin	28.92±0.05	31.15±0.02
Water absorption capacity (%)	69.88±0.92	77.95±0.56
Oil holding capacity (g/g)	1.12±0.02	1.01±0.01
Water holding capacity (g/g)	1.98±0.01	2.24±0.05
Swelling power (g/g)	8.67±0.10	6.18±0.03
Resistant starch	2.32±0.16	6.48±0.15
Total dietary fiber	7.91±0.00	8.38±0.03
Insoluble dietary fiber	3.68±0.11	5.14±0.07
Soluble dietary fiber	4.23±0.10	3.24±0.04
Antioxidant activity	25.59±0.20	15.63±0.39
Total phenolic	0.16±0.00	0.13±0.00

Color parameters: lightness (L*), redness (a*), and yellowness (b*)

2016), while jack bean flour consists of 54.03% starch, 22.88% amylose, and 31.15% amylopectin. The previous study obtained 24.70 - 36.90% starch and 17.0 - 18.42% amylose (Lawal and Adebowale, 2005; Sridhar and Seena, 2006; Acevedo *et al.*, 2013). Based on these results, canna flour had higher starch and amylose contents, while jack bean flour, had higher amylopectin content.

Resistant starch reflects a low starch digestibility rate against the digestive enzyme. Table 1 shows the resistant starch content of canna and jack bean flour was about 2.32% and 6.48%, respectively. These results are slightly lower, compared to previous studies reporting values of about 3.4% and 10.8%, respectively (Sridhar and Seena, 2006; Wandee *et al.*, 2017). Legumes, including jack bean, are known to be slowly digested by the pancreatic enzyme (Sivoli *et al.*, 2007). The resistant starch content of jack bean was compared with other legumes, including pea (4.6%), lentil (5.8%), and chickpea (6.3%) (Di *et al.*, 2020). Resistant starch content is possibly influenced by starch origin characteristics extraction process (Horstmann *et al.*, 2017), amylose content, anti-nutritional compounds (for instance, polyphenols and phytic acid) (Sridhar and Seena, 2006), as well as cooking or other food processing (Wandee *et al.*, 2017). Table 1 shows the total, insoluble, and soluble dietary fibre contents of canna flour to be about 7.91%, 3.68%, and 4.23%, respectively. Meanwhile, jack bean flour had values of about 8.38%, 5.14%, and 3.24%, respectively, indicating a higher dietary fibre profile, compared to canna flour. Furthermore, these results were lower, compared to previous studies, reporting total, insoluble, and soluble dietary fibre contents of canna flour to be about 8.59%, 3.60%, and 4.98%, respectively (Carolina and Ilmi, 2016), while jack bean flour had values of about 17.58%, 16.76%, and 0.82%, respectively (Sridhar and Seena, 2006).

Canna and jack bean flours were also discovered to have antioxidant activities of about 25.59% and 15.63%, respectively. The result of antioxidant activity indicates potential radical scavenging of the flour against synthetic DPPH radicals and indicates the flour's hydrogen donating ability. This property provides health benefits for protection against free-radical related diseases, including ageing, diabetes, and cancer (Zhang *et al.*, 2011; Vadivel *et al.*, 2012). The total phenolic content is also attributed to antioxidant activity (Shahidi and Ambigaipalan, 2015). Table 1 shows the total phenolic content of canna and jack bean flour to be about 0.16% and 0.13%, respectively. The major polyphenolic compounds in legumes are tannins, phenolic acids, and flavonoids, and these compounds are associated with the plant's seed coat colour. Legumes with dark and highly

pigmented, for instance, red kidney bean and black gram, contain the highest polyphenolic compounds (Shahidi and Ambigaipalan, 2015). Furthermore, genotype, soil, agronomic practices, environmental conditions, post-harvest storage and maturity level at harvest have contributed to the seed coat colour as well as phenolic compound content of legumes (Vadivel *et al.*, 2012). Therefore, the low total phenolic content of canna and jack bean flours may be correlated with low pigment.

3.2 Physical properties of canna flour and jack bean flour

In addition, Table 1 shows the percentage yields of canna (*ganyong*) flour and jack bean flour obtained were about 12.53% and 41.56%, respectively. Table 1 also shows the colour analysis result, while Figure 1(a) and 1(b) show the native flours' appearance. From Table 1, the L* value of canna flour was lower, compared to jack bean flour ($74.96 < 88.65$), indicating the jack bean flour obtained was brighter. Furthermore, the positive a* value of canna flour indicated the flour had a higher degree of redness, compared to jack bean flour ($2.80 > -0.80$). Canna flour's higher b* value ($16.67 > 15.10$) implied the flour is more yellow, while the darker colour is possibly influenced by the protein and carbohydrate content, inducing non-enzymatic browning (Kaushal *et al.*, 2012; Aprianita *et al.*, 2014). However, based on a previous study, canna starch had a high L* value, as well as low a* and b* values, of about 94.38, -0.06, and 1.47, respectively. Meanwhile, the colour parameters indicated canna starch had a high level of lightness with a low level of redness and yellowness, due to the high starch purity (Deng *et al.*, 2020). The flour's colour is also dependent on the raw materials pigment, determined by the plant's composition and botanical origin (Kaushal *et al.*, 2012).

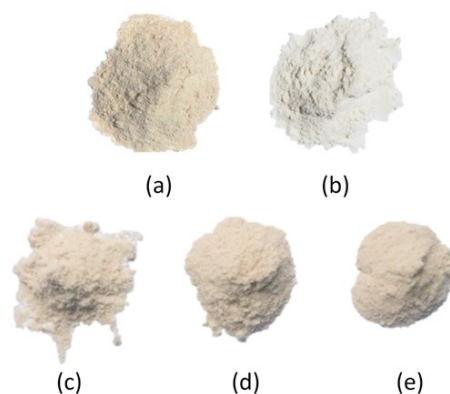


Figure 1. The appearance of (a) Canna (*Ganyong*) Flour, (b) Jack Bean Flour, Composite Flours (c) F1, (d) F2, and (e) F3.

Water absorption capacity is defined as a substance's ability to bind with water, and this determines the rancidity, body thickening, and viscosity of food

(Adebowale and Lawal, 2004; Akande *et al.*, 2013). Table 1 shows the native flour's water absorption capacity, determined to be about 69.88% and 77.95%, for canna and jack bean flour, respectively. This result is slightly lower, compared to previous studies, reporting a water absorption capacity of about 98.87 - 128.29%, for jack bean flour. The flour has a lower water absorption capacity, compared to pigeon pea and cowpea flour, due to the lower hydrophobicity (Olalekan *et al.*, 2010; Marimuthu and Gurumoorthi, 2013). This property varies, depending on protein structure and the presence of hydrophilic carbohydrate (Adebowale and Lawal, 2004). A substance's oil holding capacity plays an important role in determining the flavour retain and the mouth feel of food (Benítez *et al.*, 2013). According to Table 1, the oil holding capacity of canna and jack bean flours was about 1.12 g/g and 1.01 g/g, respectively, while the water holding capacity was about 1.98 g/g and 2.24 g/g, respectively. Water holding capacity is often influenced by porosity, particle size, ionic strength, pH, temperature, and fibre type, and is related to polysaccharide structure, indicating the presence of fibre source, including soluble dietary fibre. A study by Betancur-Ancona *et al.*, (2004) reported low soluble dietary fibre of canna fibrous starch resulted in a low water holding capacity (Betancur-Ancona *et al.*, 2004). Meanwhile, swelling power indicates the quantity of absorbable water per gram of starch, at a particular temperature. The starch granule's swelling is related to

amylopectin but inhibited by amylose, as well as complexes between lipids and amylose (Obadi and Xu, 2021). Based on Table 1, canna had a higher swelling power of about 8.67 g/g, compared to jack bean flour with a value of 6.18 g/g. However, this finding was lower, compared to previous studies, reporting values of 17.34 g/g (Marimuthu and Gurumoorthi, 2013), 7.2 g/g, and 9.6 g/g, for jack bean starch, garbanzo, and soft wheat, respectively (Romero and Zhang, 2019). High swelling power indicates starch granules with less ordered structure and weak bonding (Pérez and Lares, 2005).

3.3 Composite flour's chemical properties

Generally, proximate analysis is conducted to determine a substance or mixture's chemical composition, for further identification. Table 2 shows an increase in jack bean flour concentration significantly ($p < 0.05$) increased the composite flour's moisture, fat, and protein contents, but significantly ($p < 0.05$) reduced the ash and carbohydrate contents. This is in line with the proximate analysis of basic flour, reporting jack bean flour to have higher moisture, fat, and protein contents, as well as lower ash and carbohydrate contents, compared to canna flour. Therefore, the substitution of jack bean flour improved the composite flour's nutrition quality, especially in terms of protein content. Conversely, the substitution of wheat flour with canna

Table 2. The composite flour's chemical and physical properties

Parameter	F1	F2	F3
Proximate			
Moisture	6.91±0.03 ^a	7.15±0.00 ^b	7.45±0.02 ^c
Ash	3.78±0.01 ^c	3.31±0.02 ^b	2.87±0.02 ^a
Fat	0.80±0.00 ^a	1.35±0.02 ^b	1.93±0.07 ^c
Protein	7.04±0.04 ^a	10.45±0.01 ^b	13.69±0.00 ^c
Carbohydrate	81.47±0.02 ^c	77.75±0.04 ^b	74.06±0.06 ^a
Starch	78.81±0.08 ^c	72.79±0.64 ^b	70.73±0.24 ^b
Amylose	32.11±0.03 ^c	30.12±0.06 ^b	26.98±0.12 ^a
Amylopectin	46.70±0.05 ^b	42.67±0.69 ^a	43.75±0.36 ^a
Color			
L*	74.90±0.03 ^a	76.26±0.02 ^b	77.69±0.08 ^c
a*	2.03±0.03 ^c	1.72±0.02 ^b	1.36±0.03 ^a
b*	15.37±0.03 ^c	14.97±0.00 ^b	14.76±0.03 ^a
Water absorption capacity (%)	70.95±1.05 ^a	73.89±0.30 ^{ab}	76.13±0.40 ^b
Oil holding capacity (g/g)	0.99±0.01 ^c	0.96±0.01 ^b	0.93±0.00 ^a
Water holding capacity (g/g)	2.12±0.02 ^a	2.17±0.01 ^{ab}	2.22±0.01 ^b
Swelling power (g/g)	5.71±0.05 ^c	5.23±0.10 ^b	4.80±0.04 ^a
Resistant starch	12.84±0.07 ^a	13.12±0.04 ^b	14.59±0.04 ^c
Total dietary fiber	12.75±0.57 ^a	14.58±0.09 ^{ab}	16.35±0.59 ^b
Insoluble dietary fiber	10.25±0.55 ^a	12.29±0.00 ^b	13.42±0.14 ^b
Soluble dietary fiber	2.50±0.02 ^a	2.29±0.09 ^a	2.93±0.45 ^a
Antioxidant activity	22.68±0.37 ^b	25.09±0.19 ^c	21.19±0.37 ^a
Total phenolic	0.14±0.00 ^b	0.15±0.00 ^c	0.13±0.00 ^a

Values are presented as mean±SD. Values with different superscript within the row are significantly different at $\alpha = 0.05$.

flour significantly decreased the composite flour's protein content (Aprianita *et al.*, 2014).

The composite flours' moisture contents were below 15% (SNI 3751:2009 recommendation) and ranged from 6.91 to 7.45%, indicating shelf-life stability (BSN, 2009). In addition, the composite flours' ash contents were between 2.87 and 3.78%, implying high minerals contents, while the fat contents ranged between 0.80 to 1.93%, indicating low susceptibility to rancidity. Meanwhile, the composite flours' protein and carbohydrate contents range from 7.04 - 13.69% and 74.06 - 81.47%, respectively. The composite flours had higher protein content, compared to the minimum standard (>7%) by SNI 3751:2009 (BSN, 2009). This result is consistent with previous studies experimenting with canna and lima bean (Praseptiangga *et al.*, 2018), yam and lima bean (Utami *et al.*, 2018), as well as greater yam and jack bean-based composite flours (Affandi *et al.*, 2017). Starch is the main flour component with amylose and amylopectin structures. Table 2 shows the substitution of jack bean flour below 45% significantly ($p < 0.05$) decreased the composite flour's starch and amylopectin content, while the addition of jack bean proportionally decreased the amylose content. The reduction of starchy components, for instance, canna flour, is probably responsible for the decline in starch profile. Increasing concentration of jack bean and lima bean flours also significantly decreased the amylose content of greater yam and canna-based composite flours (Affandi *et al.*, 2017; Praseptiangga *et al.*, 2018). However, the addition of canna flour in wheat flour-based composite flours had no significant effect on the starch profile (Aprianita *et al.*, 2014).

Resistant starch reflects low digestibility of starch and is associated with high amylopectin long branch-chain as well as high gelatinization temperature, and low amylopectin short branch-chain (Huang *et al.*, 2015). The high resistant starch content also provides health benefits, including the prevention of diabetes, obesity, as well as other related diseases. Furthermore, highly resistant starch is possibly responsible for the improved texture of the end product, making the product crunchier, light and more expanded (Aprianita *et al.*, 2014). According to Table 2, an increase in jack bean flour content led to a significant ($p < 0.05$) rise in the composite flours' resistant starch contents, ranging from 12.84 to 14.59%, and this value was comparable with previous studies. A rise in lima bean content above 30% led to a significant rise in the resistant starch content of yam flour-based composite flour (Utami *et al.*, 2018), and a similar trend was obtained by substituting wheat flour with canna flour (Aprianita *et al.*, 2014). However, the substitution of greater yam flour with jack bean flour

above 30%, significantly reduced resistant starch content (Affandi *et al.*, 2017). Dietary fibre has a physiological effect like resistant starch, for instance, increasing faecal bulk weight and reducing intestinal transit time through peristaltic movements, thus, preventing constipation and colon cancer (Betancur-Ancona *et al.*, 2004). The substitution of jack bean flour below 45% led to a significant ($p < 0.05$) rise in the composite flour's insoluble dietary fibre. However, Table 2 shows this had no significant ($p > 0.05$) impact on the total and soluble dietary fibre contents. The composite flours' total, insoluble, and soluble dietary fibre contents range from 12.75 to 16.35%, 10.25 to 13.42%, and 2.50 to 2.93%, respectively. Furthermore, the dietary fibre content contained mainly insoluble dietary fibre, compared to the soluble counterpart. Based on Table 2, adding jack bean flour significant ($p < 0.05$) influenced the composite flour's antioxidant activity, with F2 having the highest result (25.09%).

However, substituting jack bean flour proportionally decreased the greater yam-based composite flour's antioxidant activity, due to jack bean flour's low antioxidant activity (Affandi *et al.*, 2017). Furthermore, the antioxidant activities of fabricated composite flours were higher, compared to 2-terbutyl-4-hydroxyanisols (BHA), as synthetic phenol with low antioxidant activity (4%). Therefore, the composite flours were a potential antioxidant alternative source and functional food ingredient, with the capacity to protect consumers from degenerative diseases (Betancur-Ancona *et al.*, 2004). Also, total phenolic content is attributed to a substance's antioxidant activity. The substitution of jack bean flour had a significant impact ($p < 0.05$) on the total phenolic content of composite flours, with F2 having the highest value (0.15%). This result was compared with previous studies. The reported substitution of jack bean and lima bean flour, which led to a significant decrease in the total phenolic content of greater yam and yam-based composite flours (Awolu, 2017; Hapsari *et al.*, 2019).

3.4 Composite flour's physical properties

Figures 1(c), 1(d), and 1(e) show the composite flours' appearances, while Table 2 shows the result of the colour analysis as well as colour parameters, L^* , a^* , and b^* values, ranging from 77.69 - 74.90, 1.36 - 2.03, and 14.76 - 15.37, respectively. An increase in jack bean flour proportion significantly ($p < 0.05$) increased the composite flours' lightness (L^*), and decreased redness (a^*) as well as yellowness (b^*). The result was comparable with a study by Aprianita *et al.* (2014), stating substituting wheat flour with canna flour led to decreased lightness and increased redness and yellowness, due to canna flour's low protein content.

Thus, the L* value was negatively associated with the flour's protein content, while the a* and b* values were positively correlated with the flour's protein level (Aprianita *et al.*, 2014).

Based on Table 2, the composite flours' water absorption capacities ranged from 70.95 to 76.13, with F3 having the highest result. This is probably associated with the protein of jack bean flour, indicating a rise in jack bean flour content increased the composite flour's water absorption capacity (Praseptiangga *et al.*, 2018). This property varies, depending on protein structure and concentration, amylose solubility and leaching, hydrophilic carbohydrate, as well as crystalline structure loss (Adebowale and Lawal, 2004; Kaushal *et al.*, 2012; Chandra *et al.*, 2014; Hasmadi *et al.*, 2020). Similarly, Awolu *et al.*, (2017), reported the addition of kidney beans to pearl millet and tiger nut flour-based composite flours led to a significant rise in the flour's water absorption capacity. The high water absorption capacity was useful in product bulking, body thickening, consistency, as well as viscosity (Vadivel and Janardhanan, 2001; Utami *et al.*, 2018).

Table 2 shows substituting jack bean flour significantly ($p < 0.05$) reduced the composite flours' oil holding capacity, with F1 having the highest result (0.99 g/g). This result was consistent with previous studies, reporting the substitution of canna and yam flours with lima bean significantly decreased the oil holding capacity, due to the flours' lower hydrophobic protein content (Praseptiangga *et al.*, 2018; Utami *et al.*, 2018). In addition, oil holding capacity was associated with soluble dietary fibre content, with organic compounds (for instance, biliary acids) adsorption ability. Soluble dietary fibre sources, including lignin and hemicelluloses, are able to trapped oil on the fibre surface (Betancur-Ancona *et al.*, 2004). Also, the water holding capacity plays an important role, in determining the final products' texture and size (Ashraf *et al.*, 2012). According to Table 2, adding jack bean flour led to a slight increase in the composite flours' water holding capacity, ranging from 2.12 to 2.22 g/g. A similar finding was obtained with the substitution of yam-based composite flours with lima bean flour (Utami *et al.*, 2018). The carbohydrate structure, pH, porosity, ionic strength, particle size, temperature, as well as fibre type are factors influencing the flours' water holding capacity (Betancur-Ancona *et al.*, 2004).

Table 2 shows substituting jack bean flour significantly ($p < 0.05$) reduced the composite flours' swelling power, ranging between 4.80 to 5.71 g/g. The decline in the composite flour's swelling power is probably associated with a reduced starchy component,

resulting in lower starch, amylose, as well as amylopectin contents. Conversely, substituting canna flour and potato flour increased the swelling power of wheat-based composite flours, due to the high starch content (Aprianita *et al.*, 2014; Chandra *et al.*, 2014). The high protein content of jack bean flour facilitates the ability to form a complex structure with amylose and restricts swelling power. Swelling power is influenced by the amylose and amylopectin ratio, size of granule, amylopectin branching degree and chain length, crystalline structure, lipid, as well as protein content (Huang *et al.*, 2015). Generally, the low amylose content of starch contributes to high swelling power (Deng *et al.*, 2020). For instance, the addition of lima bean flour significantly increased swelling power and reduced the amylose content of canna-based composite flours (Praseptiangga *et al.*, 2018). The fabricated composite flours had reduced swelling power and low amylose content, however, further analysis is required for comprehensive information.

3.5 Determination of the best formula for composite flours

The most suitable composite flour formula was determined by scoring the results of physicochemical analysis. Each parameter was scored between 0 and 1, indicating the parameter's influence on the samples' characteristics. In this study, each parameter was assumed to have a similar contribution, and therefore had a score of 1 (De Garmo and Sullivan, 1984). The result of the calculation is presented in Table 3. Based on the results, F1, F2, and F3 obtained scores of 0.449, 0.500, and 0.486, respectively. Thus, F2 had the highest result and was therefore selected as the best composite flour formula.

4. Conclusion

This study successfully manufactured canna flour and jack bean-based composite flours, and these flours had consistent physical and chemical properties with native flours. Furthermore, the substitution of jack bean flour significantly ($p < 0.05$) influenced the proximate composition, swelling power, oil holding capacity, lightness, and resistant starch content of canna flour-based composite flours. According to the results, F2 (70% canna flour and 30% jack bean flour) had the best formula. However, further investigations on bioaccessibility and bioavailability of composite flour bioactive compounds, both in vitro and in vivo, are required to encourage the composite flour's utilization as a functional food ingredient, especially for gluten-related diseases and diabetic patients.

Table 3. Determination of the best formula of composite flours

Parameter	Result value			Worst value	VW	NW	F1		F2		F3	
	F1	F2	F3				Best value	NV	Score	NV	Score	NV
Physical Characteristics												
Color (L*)	74.895	76.255	77.685	74.895	1.000	0.059	0.000	0.000	0.487	0.029	1.000	0.059
WAC (%)	70.951	73.889	76.125	70.951	1.000	0.059	0.000	0.000	0.568	0.033	1.000	0.059
OHC (w/w)	0.987	0.957	0.928	0.928	1.000	0.059	1.000	0.059	0.492	0.029	0.000	0.000
WHC (w/w)	2.116	2.170	2.219	2.116	1.000	0.059	0.000	0.000	0.524	0.031	1.000	0.059
Swelling power (w/w)	5.709	5.230	4.799	4.799	1.000	0.059	1.000	0.059	0.474	0.028	0.000	0.000
Chemical characteristics												
Moisture	6.909	7.149	7.449	6.909	1.000	0.059	0.000	0.000	0.444	0.026	1.000	0.059
Ash	3.779	3.309	2.873	2.873	1.000	0.059	1.000	0.059	0.481	0.028	0.000	0.000
Fat	0.798	1.346	1.929	0.798	1.000	0.059	0.000	0.000	0.485	0.029	1.000	0.059
Protein	7.038	10.451	13.691	7.038	1.000	0.059	0.000	0.000	0.513	0.030	1.000	0.059
Carbohydrate	81.472	77.747	74.061	74.061	1.000	0.059	1.000	0.059	0.497	0.029	0.000	0.000
Total starch	78.812	72.780	70.729	70.729	1.000	0.059	1.000	0.059	0.254	0.015	0.000	0.000
Amylose	32.112	30.115	26.977	26.977	1.000	0.059	1.000	0.059	0.611	0.036	0.000	0.000
Amylopectin	46.701	42.665	43.752	42.665	1.000	0.059	1.000	0.059	0.000	0.000	0.269	0.016
Resistant starch	12.836	13.121	14.591	12.836	1.000	0.059	0.000	0.000	0.162	0.010	1.000	0.059
Total dietary fiber	12.750	14.580	16.346	12.750	1.000	0.059	0.000	0.000	0.509	0.030	1.000	0.059
Antioxidant activity	22.676	25.093	21.189	21.189	1.000	0.059	0.381	0.022	1.000	0.059	0.000	0.000
Total phenolic	0.137	0.149	0.133	0.133	1.000	0.059	0.250	0.015	1.000	0.059	0.000	0.000
Total					17.000	1.000	0.449		0.500		0.486	

VW: variable weight, NW: normalization weight, NV: non-dimensional value, WAC: water absorption capacity, OHC: oil holding capacity, WHC: water holding capacity

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

The authors are thankful to the Directorate of Research and Community Services, the Indonesian Ministry of Research, Technology, and Higher Education, and Universitas Sebelas Maret (UNS) for the provision of support and a research grant of PKLP-UNS No.260/UN27.22/HK.07.00/2021 towards this study.

References

- Acevedo, B.A., Avanza, M.V, Chaves, M.G. and Ronda, F. (2013). Gelation, thermal and pasting properties of pigeon pea (*Cajanus cajan* L.), dolichos bean (*Dolichos lablab* L.) and jack bean (*Canavalia ensiformis*) flours. *Journal of Food Engineering*, 119 (1), 65–71. <https://doi.org/10.1016/j.jfoodeng.2013.05.014>
- Adebowale, K.O. and Lawal, O.S. (2004). Comparative study of the functional properties of bambarra groundnut (*Voandzeia subterranean*), jack bean (*Canavalia ensiformis*) and mucuna bean (*Mucuna pruriens*) flours. *Food Research International*, 37(4), 355–365. <https://doi.org/10.1016/j.foodres.2004.01.009>
- Affandi, D.R., Praseptiangga, D., Nirmala, F.S., Amanto, B.S. and Atmaka, W. (2017). Physical and Chemical Characterization Of Greater Yam (*Dioscorea Alata*) And Jack Bean (*Canavalia Ensiformis*) - Based Composite Flour. *IOP Conference Series: Materials Science and Engineering*, 193(1), 012041. <https://doi.org/10.1088/1757-899X/193/1/012041>
- Agbede, J.O. and Aletor, V.A. (2005). Studies of the chemical composition and protein quality evaluation of differently processed *Canavalia ensiformis* and *Mucuna pruriens* seed flours. *Journal of Food Composition and Analysis*, 18(1), 89–103. <https://doi.org/10.1016/j.jfca.2003.10.011>
- Akande, E.A., Oladipo, A.O. and Kelani, O.S. (2013). Effects of steaming on the physicochemical properties and the cooking time of jack bean (*Canavalia ensiformis*). *Journal of Experimental Biology and Agricultural Sciences*, 1(6), 420–423
- AOAC. (2005). Official Methods of Analysis of the Association of Official Agricultural Chemists. Virginia, USA: Arlington, Inc.
- Aprianita, A., Vasiljevic, T., Bannikova, A. and Kasapis, S. (2014). Physicochemical properties of wheat-canna and wheat-konjac composite flours. *Journal of Food Science and Technology*, 51(9), 1784–1794. <https://doi.org/10.1007/s13197-012-0696-x>
- Ariyantoro, A.R., Amanto, B.S. and Kristin, A.N. (2020). The physical, chemical, and sensory properties of sweet bread from jack bean flour modified with acetic acid. *AIP Conference Proceedings*, 2219, 070006. <https://doi.org/10.1063/5.0003134>
- Ashraf, S., Saeed, S.M.G., Sayeed, S.A. and Ali, R. (2012). Impact of Microwave Treatment on the Functionality of Cereals and Legumes. *International Journal of Agriculture and Biology*, 14(3), 365–370
- Asp, N.G., Johansson, C.G., Hallmer, H. and Siljestroem, M. (1983). Rapid enzymatic assay of insoluble and soluble dietary fiber. *Journal of Agricultural Food Chemistry*, 31(3), 476–482. <https://doi.org/10.1021/jf00117a003>
- Awolu, O.O. (2017). Optimization of the functional characteristics, pasting and rheological properties of pearl millet-based composite flour. *Heliyon*, 3(2), e00240. <https://doi.org/10.1016/j.heliyon.2017.e00240>
- Benítez, V., Cantera, S., Aguilera, Y., Mollá, E., Esteban, R.M., Díaz, M.F. and Martín-Cabrejas, M.A. (2013). Impact of germination on starch, dietary fiber and physicochemical properties in non-conventional legumes. *Food Research International*, 50(1), 64–69. <https://doi.org/10.1016/j.foodres.2012.09.044>
- Betancur-Ancona, D., Peraza-Mercado, G., Moguel-Ordoñez, Y. and Fuertes-Blanco, S. (2004). Physicochemical characterization of lima bean (*Phaseolus lunatus*) and Jack bean (*Canavalia ensiformis*) fibrous residues. *Food Chemistry*, 84(2), 287–295. [https://doi.org/10.1016/S0308-8146\(03\)00213-9](https://doi.org/10.1016/S0308-8146(03)00213-9)
- BSN. (2009). Terms of Wheat Flour as Food Ingredient (SNI 3751:2009). Jakarta, Indonesia: National Standardization Agency
- Burhannudin, Mahmudah, N., Widyarini, S. and Purnomosari, D. (2018). Chemopreventive Effects of Edible Canna (*Canna edulis* Kerr.) Against Colorectal Carcinogenesis : Effects on Expression of Adenomatous Polyposis Coli and Inducible Nitric Oxide Synthase in Rat Inflammatory Model. *Asian Pasific Journal of Cancer Prevention*, 19(3), 839–844. <https://doi.org/10.22034/APJCP.2018.19.3.839>
- Carolina, A. and Ilmi, F.N. (2016). Production of Indonesian *Canna edulis* type IV resistant starch through acetylation modification. *International Food Research Journal*, 23(2), 491–497
- Chandra, S., Singh, S. and Kumari, D. (2014). Evaluation of functional properties of composite flours and sensorial attributes of composite flour

- biscuits. *Journal of Food Science and Technology*, 52(June), 3681–3688. <https://doi.org/10.1007/s13197-014-1427-2>
- Chau, C.F. and Huang, Y.L. (2003). Comparison of the chemical composition and physicochemical properties of different fibres prepared from the peel of *Citrus sinensis* L. cv. Liucheng. *Journal of Agriculture and Food Chemistry*, 51(9), 2615–2618. <https://doi.org/10.1021/jf025919b>
- Deng, M., Reddy, C.K. and Xu, B. (2020). Morphological, physico-chemical and functional properties of underutilized starches in China. *International Journal of Biological Macromolecules*, 158, 648–655. <https://doi.org/10.1016/j.ijbiomac.2020.05.031>
- Di, M., Condelli, N., Carmela, M., Marti, A., Cela, N. and Galgano, F. (2020). Functional properties and predicted glycemic index of gluten free cereal, pseudocereal and legume flours. *LWT*, 133, 109860. <https://doi.org/10.1016/j.lwt.2020.109860>
- Doss, A., Pugalenti, M., Vadivel, V.G., Subhashini, G. and Subash, R.A. (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
- Faheina-Martins, G.V., da Silveira, A.L., Cavalcanti, B.C., Ramos, M.V, Moraes, M.O., Pessoa, C. and Araújo, D.A.M. (2012). Antiproliferative effects of lectins from *Canavalia ensiformis* and *Canavalia brasiliensis* in human leukemia cell lines. *Toxicology in Vitro*, 26(7), 1161–1169. <https://doi.org/10.1016/j.tiv.2012.06.017>
- De Garmo, E.P. and Sullivan, W.G. (1984). *Engineering Economics*. 7th ed. New York, USA: Macmillan Pub. Co.
- Goni, I., Garcia-Diz L., Manas, E. and Saura-Calixto, F. (1996). Analysis of resistant starch: a method for foods and food products. *Food Chemistry*, 56(4), 445–449. [https://doi.org/10.1016/0308-8146\(95\)00222-7](https://doi.org/10.1016/0308-8146(95)00222-7)
- Hapsari, F., Naufalin, R., Agustia, F.C. and Rukmini, H.S. (2019). Breakfast development based on jack bean and analysis of physical, chemical and sensory product. *IOP Conference Series: Earth and Environmental Science*, 250, 012033. <https://doi.org/10.1088/1755-1315/250/1/012033>
- Hasmadi, M., Noorfarahzilah, M., Noraidah, H., Zainol, M.K. and Jahurul, M.H. (2020). Functional properties of composite flour: a review. *Food Research*, 4(6), 1820–1831. [https://doi.org/10.26656/fr.2017.4\(6\).419](https://doi.org/10.26656/fr.2017.4(6).419)
- Haupt-Jorgensen, M., Holm, L., Josefsen, K. and Buschard, K. (2018). Possible Prevention of Diabetes with a Gluten-Free Diet. *Nutrients*, 10(11), 1746. <https://doi.org/10.3390/nu10111746>
- Horstmann, S., Lynch, K. and Arendt, E. (2017). Starch Characteristics Linked to Gluten-Free Products. *Foods*, 6(4), 29. <https://doi.org/10.3390/foods6040029>
- Huang, J., Zhao, L., Man, J., Wang, J., Zhou, W., Huai, H. and Wei, C. (2015). Comparison of physicochemical properties of B-type nontraditional starches from different sources. *International Journal of Biological Macromolecules*, 78, 165–172. <https://doi.org/10.1016/j.ijbiomac.2015.04.006>
- Hutchings, J.B. (2017). Colour in food. In Best, J. (Ed.), *Colour Design: Theories and Applications*. 2nd ed. USA: Woodhead Publishing. <https://doi.org/10.1016/B978-0-08-101270-3.00006-0>
- Imai, K. (2008). Edible Canna: A Prospective Plant Resource from South America. *Japanese Journal of Plant Science*, 2(2), 46–53.
- Kaushal, P., Kumar, V. and Sharma, H.K. (2012). Comparative study of physicochemical, functional, antinutritional and pasting properties of taro (*Colocasia esculenta*), rice (*Oryza sativa*) flour, pigeonpea (*Cajanus cajan*) flour and their blends. *LWT - Food Science and Technology*, 48(1), 59–68. <https://doi.org/10.1016/j.lwt.2012.02.028>
- Lawal, O.S. and Adebawale, K.O. (2005). Physicochemical characteristics and thermal properties of chemically modified jack bean (*Canavalia ensiformis*) starch. *Carbohydrate Polymers*, 60(3), 331–341. <https://doi.org/10.1016/j.carbpol.2005.01.011>
- Leach, H.W., McCowen, L.D. and Scoch, T.J. (1959). Structure of the starch granule I. Swelling and solubility patterns of various starches. *Cereal Chemistry Journal*, 36, 534–544
- Marimuthu, M. and Gurumoorthi, P. (2013). Physicochemical and functional properties of starches from Indian Jack bean (*Canavalia ensiformis*), an underutilized wild food legume. *Journal of Chemical and Pharmaceutical Research*, 5(1), 221–225
- Melini, V. and Melini, F. (2019). Gluten-Free Diet: Gaps and Needs for a Healthier Diet. *Nutrients*, 11(1), 170. <https://doi.org/10.3390/nu11010170>
- Myhrstad, M.C.W., Slydahl, M., Hellmann, M., Garnweidner-Holme, L., Lundin, K.E.A., Henriksen, C. and Telle-Hansen, V.H. (2021). Nutritional quality and costs of gluten-free products: a case-control study of food products on the Norwegian market. *Food and Nutrition Research*, 65, 6121.

- <https://doi.org/10.29219/fnr.v65.6121>
- Mir, J. A., Srikaeo, K. and García, J. (2013). Effects of amylose and resistant starch on starch digestibility of rice flours and starches. *International Food Research Journal*, 20(3), 1329–1335.
- Mishra, T., Das, A.P. and Sen, A. (2012). Phytochemical Screening and In-vitro Antioxidant Profiling of Solvent Fractions of *Canna edulis* Ker Gawler. *Free Radicals and Antioxidants*, 2(1), 13–20. <https://doi.org/10.5530/ax.2012.2.5>
- Molyneux, P. (2004). The use of the stable free radical diphenylpicryl-hydrazyl (DPPH) for estimating antioxidant activity. *Songklanakarin Journal of Science and Technology*, 26(2), 212–219
- Romero, H.M. and Zhang, Y. (2019). Physicochemical properties and rheological behavior of flours and starches from four bean varieties for gluten-free pasta formulation. *Journal of Agriculture and Food Research*, 1, 100001. <https://doi.org/10.1016/j.jafr.2019.100001>
- Niland, B. and Cash, B.D. (2018). Health Benefits and Adverse Effects of a Gluten-Free Diet in Non – Celiac Disease Patients. *Gastroenterology and Hepatology*, 14(2), 82–91
- Nugraheni, M., Sutopo, Purwanti, S. and Handayani, T. (2019). The Development of gluten and eggs-free Cookies Enriched with *Canna edulis* flour rich in Resistant Starch Type 3 as a Functional. *Journal of Physics: Conference Series*, 1387, 012006. <https://doi.org/10.1088/1742-6596/1387/1/012006>
- Obadi, M. and Xu, B. (2021). Review on the physicochemical properties, modifications, and applications of starches and its common modified forms used in noodle products. *Food Hydrocolloids*, 112, 106286. <https://doi.org/10.1016/j.foodhyd.2020.106286>
- Olalekan, A.J., Bosede, B.F., Polytechnic, R.G., State, O. and State, O. (2010). Comparative Study on Chemical Composition and Functional Properties of Three Nigerian Legumes (Jack Beans, Pigeon Pea and Cowpea). *Journal of Emerging Trends in Engineering and Applied Sciences*, 1(1), 89–95.
- Pérez, E. and Lares, M. (2005). Chemical Composition, Mineral Profile, and Functional Properties of *Canna* (*Canna edulis*) and Arrowroot (*Maranta* spp.) Starches. *Plant Foods for Human Nutrition*, 60(3), 113–116. <https://doi.org/10.1007/s11130-005-6838-9>
- Praseptiangga, D., Tryas, A.A., Affandi, D.R., Atmaka, W., Ariyantoro, A.R. and Minardi, S. (2018). Physical and chemical characterization of composite flour from canna flour (*Canna edulis*) and lima bean flour (*Phaseolus lunatus*). *AIP Conference Proceedings*, 1927(1), 030020. <https://doi.org/10.1063/1.5021213>
- Rusyidi, M.M.R. and Azrina, A. (2012). Effect of germination on total phenolic, tannin, and phytic acid content in soy bean and peanut. *International Food Research Journal*, 19(2), 673–677.
- Santacruz, S., Pennanen, M. and Ruales, J. (2009). Protein enrichment of oriental noodles based on *Canna edulis* starch. *Asian Journal of Food and Agro-Industry*, 2(4), 521–538
- Shahidi, F. and Ambigaipalan, P. (2015). Phenolics and polyphenolics in foods, beverages and spices: Antioxidant activity and health effects – A review. *Journal of Functional Foods*, 18(Part B), 820–897. <https://doi.org/10.1016/j.jff.2015.06.018>
- Sívoli, L., Michelangeli, C., Pérez, E., Méndez, A. and Tovar, J. (2007). Starch digestibility and morphology of physically modified jack bean (*Canavalia ensiformis* L.) seed flours. *Animal Feed Science and Technology*, 136(3–4), 338–345. <https://doi.org/10.1016/j.anifeedsci.2007.01.013>
- Sosulski, F.W., Garatt, M.O. and Slinkard, A.E. (1976). Functional properties of ten legume flours. *International Journal of Food Science and Technology*, 9(2), 66–69. [https://doi.org/10.1016/S0315-5463\(76\)73614-9](https://doi.org/10.1016/S0315-5463(76)73614-9)
- Sridhar, K.R. and Seena, S. (2006). Nutritional and antinutritional significance of four unconventional legumes of the genus *Canavalia* – A comparative study. *Food Chemistry*, 99(2), 267–288. <https://doi.org/10.1016/j.foodchem.2005.07.049>
- Suhartini, T. and Hadiatmi. (2010). Morphological Characteristics Variability of *Canna* (*Canna edulis* Ker.) (Keragaman Karakter Morfologi Tanaman Ganyong). *Buletin Plasma Nuftah*, 16(2), 118–125. <https://doi.org/10.21082/blpn.v16n2.2010.p118-125>
- Ugwuona, F.U. and Suwaba, S. (2013). Effects of Defatted Jack Bean Flour and Jack Bean Protein Concentrate on Physicochemical and Sensory Properties of Bread. *Nigerian Food Journal*, 31(2), 25–32. [https://doi.org/10.1016/S0189-7241\(15\)30073-4](https://doi.org/10.1016/S0189-7241(15)30073-4)
- UNSCN. (2018). United Nations System Standing Committee on Nutrition: Non-communicable diseases. Rome, Italy: UNSCN.
- Utami, R.F., Praseptiangga, D., Affandi, D.R. and Atmaka, W. (2018). Formulation and physicochemical characterization of composite flour from yam (*Dioscorea alata*) and lima beans (*Phaseolus lunatus*). in *AIP Conference Proceedings*, 1927, 030019. <https://doi.org/10.1063/1.5021212>

- Vadivel, V., Cheong, J.N. and Biesalski, H.K. (2012). Antioxidant and type II diabetes related enzyme inhibition properties of methanolic extract of an underutilized food legume, *Canavalia ensiformis* (L.) DC: Effect of traditional processing methods. *LWT*, 47(2), 255–260. <https://doi.org/10.1016/j.lwt.2012.01.014>
- Vadivel, V. and Janardhanan, K. (2001). Diversity in nutritional composition of wild jack bean (*Canavalia ensiformis* L. DC) seeds collected from south India. *Food Chemistry*, 74(4), 507–511. [https://doi.org/10.1016/S0308-8146\(01\)00175-3](https://doi.org/10.1016/S0308-8146(01)00175-3)
- Wahjuningsih, S.B. and WyatiSaddewisasi. (2013). Pemanfaatan koro pedang pada aplikasi produk pangan dan analisis ekonominya. *Riptek*, 7(2), 1–10. [In Bahasa Indonesia].
- Wandee, Y., Uttapap, D., Pucha-arnon, S., Puttanlek, C., Rungsardthong, V. and Wetprasit, N. (2015). Quality assessment of noodles made from blends of rice flour and canna starch. *Food Chemistry*, 179, 85–93. <https://doi.org/10.1016/j.foodchem.2015.01.119>
- Wandee, Y., Uttapap, D., Pucha-arnon, S., Puttanlek, C., Rungsardthong, V. and Wetprasit, N. (2017). *In vitro* fermentabilities of raw and cooked canna starches and their derivatives. *Journal of Functional Foods*, 34, 461–469. <https://doi.org/10.1016/j.jff.2017.05.004>
- Welli, Y., Agnes, M., Yudi, P. and Yustinus, M. (2020). The effect of mixture of banana pseudostem flour proportion on organoleptic properties, dietary fiber content, resistant starch, and antioxidants of canna starch-based food bar. *Food Research*, 4(3), 906–916. [https://doi.org/10.26656/fr.2017.4\(3\).382](https://doi.org/10.26656/fr.2017.4(3).382)
- WHO. (2018). Noncommunicable diseases: country profile 2018. Geneva, Switzerland: WHO.
- Zhang, C., Ma, S., Wu, J., Luo, L., Qiao, S., Li, R., Xu, W., Wang, N., Zhao, B., Wang, Xiao, Zhang, Y. and Wang, X. (2020). A specific gut microbiota and metabolomic profiles shifts related to antidiabetic action: The similar and complementary antidiabetic properties of type 3 resistant starch from *Canna edulis* and metformin. *Pharmacological Research*, 159, 104985. <https://doi.org/10.1016/j.phrs.2020.104985>
- Zhang, J., Wang, Z. and Mi, Q. (2011). Phenolic compounds from *Canna edulis* Ker residue and their antioxidant activity. *LWT - Food Science and Technology*, 44(10), 2091–2096. <https://doi.org/10.1016/j.lwt.2011.05.021>