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Physicochemical and functional characteristics of black potato (*Coleus tuberosus*) flour from some locations in East Java Indonesia

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KEYWORDS

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ABSTRACT

Coleus tuberous (local name: *kentang hitam*/black potato) is widely available in Indonesia. Commonly, black potatoes are only boiled and made into side dishes. Black potatoes have the potential to be the ingredient of functional foods. However, black potatoes can only be harvested once a year. Therefore, a low moisture form (flour) storage is required for longer shelf life. Research on physicochemical and functional characteristics of black potato flour is expected to widen the use of black potato flour as raw materials in various food products. This study aimed to analyze the chemical, physical, and functional characteristics of black potato flour originating from Sunthi (Jaten), Begal, and Kopenan Forest villages in East Java, Indonesia. All the measurements for physical, chemical, and functional characteristics were carried out with three replications. The data was then analyzed using one-way ANOVA, followed by the Tukey test to find the difference from each sample at a 0.05 significance level. The correlation analysis and principal component analysis were also subjected to study the relationship between each character of the samples. The result indicated that the tuber and starch have relatively high ash, amylose, and total phenol concentration. Several high correlations were found between the characteristics of the black potato flours. One of the high correlations was the water absorption index with starch, amylose, and total phenolic content. The principal component analysis (PCA) also found that the three samples were loading differently in the score plot. Two first principal components (PCs) were the contributing factor for 100% of the differences.

Introduction

Black potatoes (*Coleus tuberosus*) are one of the tubers in Indonesia which has the potential to be developed to enrich the diversity of Indonesian carbohydrate sources. Mandasari et al. (2015) confirmed that black potatoes are one of the non-rice foods not widely known to the public. Today, black potatoes are consumed by boiling, steaming, or made as side dishes with simple processing. Some of the black potato-producing regions are Sumatra, Java, Kalimantan, Nusa Tenggara, and Maluku (Syarif, 2015). In East Java, black potatoes are found in Ngawi, Madiun, Magetan, Bojonegoro, and Lamongan.

Black potatoes have the potential to be developed into functional food (Chandrasekara and Kumar, 2016), yet their application has not been widely made. Black potatoes are annual plants and can only be harvested once a year. Thus, the production of black potatoes is seasonal. Black potatoes will reach the maximum potential as flour and be applied to food with a long shelf life. Previous studies on black potatoes were mostly focused on improving cultivation and cellular activity as health benefits (Nugraheni et al., 2015; Nugrahaeni et al., 2014; Hsum et al., 2011; Lim, 2002). Another research on the genetics of black potatoes in Java has been done on those growing in Ngawi (Yulita et al., 2014). Mandasari et al. (2015) have modified black potato flour using acetic acid.

Research on the physicochemical content of black potato flour is still not widely done. The content of black potatoes is deemed necessary to

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be explored to increase utilization in the future. The urge to examine the functional properties of black potato flour is to understand its functional characteristics when applied to food products. In this study, we examine the physicochemical and functional properties of black potato flour originating from several regions in East Java, including Begal Village and Kopenan Forest (in Jogorogo District), and Sunthi Village (in Kedunggalar District). The knowledge is expected to expand the use of black potatoes in various food products for the community.

Research Methods

Materials

Black potatoes were obtained from three regions in Ngawi, including Begal Village and Hutan Kopenan Village in Jogorogo District and Sunthi Village in Kedunggalar District. Black potatoes were harvested in the dry season with a maximum diameter of 2-3 cm. The materials used for the analysis were distilled water, canola oil, ethanol 95% (containing 0,025% thymol blue), KOH 0,2 N, ethanol 95%, sodium hydroxide (NaOH) 1 N, acetic acid 1 N, iodine in KI 2%, Kjeldahl reagent, H_2SO_4 phenolphthalein, *methyl red*, HCl 0,1 N, petroleum ether, Na-carbonate alkalis 2%, folin-Cocteau reagent, petroleum ether, HCl 25%, NaOH 45%, and nelson reagent.

Sample Preparation

Black potatoes were washed and then cut using a 2 mm thick slicer without peeling. The potatoes were then soaked in water containing 0.4% (400 ppm) of sodium metabisulfite for 1 hour. Then, dried using a cabinet dryer at 60^{o}C for 8 hours before being grounded and sieved using 80 mesh sieves.

Chemical Characteristics Determination

The chemical analysis includes analysis of water content 925.10 (AOAC, 2005), ash content 923.03 (AOAC, 2005), fat content 920.85 (AOAC, 2005), protein content 920.87 (AOAC, 2005), starch content (Clegg, 1956), amylose content (Perez and Juliano, 1978), and total phenol levels by the Folin Ciocalteau method (Naczk and Shahidi, 2019). Each observation was carried out in triplicate. All chemicals used are pro analysis.

Physical Characteristics Determination

Physical analysis carried out includes color (Tsaalitsati et al., 2016), yield (Dansby and Bovell-Benjamin, 2003), and Kamba density (Lalel et al., 2009). Each observation was carried out in triplicate.

Functional Characteristics Determination

Observation of functional characteristics of flour was carried out, including the solubility index (Singh and Singh, 1991), the water absorption index (Niba et al., 2002, gel consistency (Williams, 1963), oil absorption index (Niba et al., 2002), and swelling properties (Leach et al., 1961). All solvents used were pro analysis.

Statistical Analysis

The analysis was done in triplicate and the results obtained were subjected to one-way`1 analysis of variance (ANOVA) and Tukey test at 0.05 significance level using Minitab 16. Analysis of correlation and principal component of analysis was done to study attribute sample relationship using Minitab 16

Results and Discussion

Chemical Characteristics

Black potatoes usually grow on dry land with various levels of dryness. This plant grows well under trees and with direct sunlight. Planting is done with tubers in high rainfall months around December to January; harvest can be done after 4 to 5 months in the dry season from May to August. The chemical content of black potatoes depends on where the plants grow. The chemical characteristics of black potato flour in several locations are presented in Table 1.

The ash content of black potato flour ranges from 4 to 5%. In Nigeria, black potatoes (*Hausa potato*) generally have mineral contents, such as calcium (17 mg/100 mg) and iron (6 mg/100 mg) (Enyiukwu et al., 2014). The ash content of black potatoes is higher than the ash content of taro (1.3%) and potatoes (1.9%), yet lower than that of sweet potatoes (4.4%) (Kaur et al., 2011; Kamal et al., 2014). The level of ash shows the mineral content of tubers. Muchtadi (1997) states that the proportion of ash content in food can also be influenced by various factors such as soil nutrients, plant maturity, climate, location, and planting treatment.

Table 1. The chemical characteristics of black potato flour from several locations in East Java

Chemical Characteristics	Begal Village	Sunthi Village	Kopenan Forest
Ash content (%ww)	4.43±0.22^{b}	6.01±0.64^{a}	5.15±0.06^{ab}
Water content (%ww)	7.71±0.22^{a}	6.55±0.06^{b}	6.50±0.01^{b}
Fat content (%ww)	1.60±0.13^{a}	1.10±0.37^{a}	1.53±0.49^{a}
Protein content (%ww)	4.60±0.10^{b}	5.97±0.10^{a}	5.97±0.05^{a}
Starch content (%ww)	70.02±6.58^{a}	47.20±0.99^{b}	51.39±1.59^{b}
Amylose content (%ww)	24.98±0.22^{a}	20.84±0.08^{b}	21.59±1.01^{b}
Total phenol (g/100g)	3.17± 0.36^{b}	4.82± 0.06^{a}	4.34 ±0.40^{a}

Note: Values are expressed as mean ±SD. Means having different letters within the same row differs significantly at p ≤0.05

The sample was dried in the cabinet drier to reduce the water content. The moisture content of black potato flour that grows in three regions in East Java is 6.5 to 7.7%. The water content of the flour is a crucial parameter because it determines the quality and shelf life of flour. Aryee et al. (2006) confirm that a tuber's low water content can maintain the flour's quality during storage. On the quality requirements of cassava flour (SNI 01-2997-1992), the maximum permissible water content is 12%. According to Susilawati et al. (2008), differences in water content can be influenced by differences in planting locations that are related to soil fertility. Loose soil will make it easier for the tuber to grow optimally as the roots easily penetrate the soil.

The presence of fat can inhibit the absorption of water and swelling properties of starch due to the presence of a hydrophobic fat layer around starch granules. The fat content of black potato flour in this study is almost the same (1.1-1.6%) and is higher than the fat content of sweet potato (0.89%), taro from Cameroon (0.3-1.17%), and potatoes (0.3%), yet lower than sweet potato (2.6%) (Kamal et al., 2013; Aboubakar et al., 2008; Noman et al., 2007). Commonly, the fat content of tubers is low. The fat content of tubers may affect the oil absorption index.

The protein content of flour affects the initial temperature of gelatinization; the higher the protein content, the higher the initial gelatinization temperature. This is because proteins can form complexes with amylose to form deposits that do not dissolve and inhibit the release of amylose from granules. The presence of protein also adds to flour's nutritional value and can affect oil absorption properties. In this study, the protein levels in black potatoes are around 4.6 to 5.97%. The protein content of black potatoes is higher than in other popular tubers of potatoes and sweet potatoes (2.73 and 0.57%) (Noman et al., 2007). However, this value is still lower than other superior flour, wheat, which has a protein content of 8.4% (Sanchez-Marinez et al., 1997).

The starch content of black potato flour originating from Begal Village is 70.02%, while the starch content from Sunthi and Kopenan Forest is 47.20 and 51.39%. The starch content of black potato (*Hausa potato*) studied in Nigeria is 15.14 ± 0.05% (Ukpabi et al., 2011). According to Mukherjee et al. (2015), the Sree Dhara variety's starch content of the Chinese potato is 18.8%, and Callus reg.SD is 20%. The difference in starch content can be influenced by the age of harvesting, where the time needed to reach maturity differs depending on the climate and location of planting (Radley, 1976).

Amylose content in flour determines the heat and swelling characteristics of the flour when processed (Blazek et al., 2008). In this study, amylose content in black potato flour is 20.84 to 24.98%. Flour with high amylose content can be used to replace rice flour in making rice paper; it also has the potential to replace wheat flour to be processed into a snack partially. Amylose in flour can strengthen and facilitate dough cutting to produce a crunchy texture (Taggart, 2004). Flour with high amylose content is suitable for making sauces, salad dressings, and mayonnaise (Craig et al., 1989).

Black potato flour from Begal Village has a total phenol content of 3.17 ± 0.36 g/100g, Sunthi Village has the highest total phenol content of 4.82 ± 0.06g/100g, and Kopenan Forest has a total phenol content of 4.34 ± 0.40 g/100g. This value is higher than the total phenol of buckwheat flour, cowpea, and chickpeas at 0.313, 0.108, and 0.121 g/100 g (Quittier-Deleu et al., 2000; Sreerama et al., 2012). Phenolic compounds are bioactive compounds good for health that can act as antioxidants (Laeliocattleya et al., 2018). However, the presence of phenolic compounds will affect the product’s color. According to Burrel (1984), browning tubers have a relationship with phenol levels; the higher the phenol content, the darker the product’s color will be.

Physical Characteristics

The color of the black potato flour is brownish, so the brightness level is also quite low. The brightness level (L value) of black potato flour is as follows: from Begal Village> Kopenan Forest > Sunthi Village (74.03> 70.4> 68.6). Sodium metabisulfite is used to reduce the brownish level of flour. The brown color of black potato flour comes from a phenolic compound naturally found in black potatoes. Because of its color, black potato flour is unsuitable for making white food products such as white bread or white mayonnaise.

Differences are found in the analysis of black potato flour yield. The yield of black potato flour is as follows: from Begal Village> Sunthi Village> Kopenan Forest (25.38> 19.27> 18.31%). The order of this yield corresponds to the order of total starch (Table 1). The higher the starch content of a tuber, the greater the flour yield.

Kamba density is the ratio between a material's weights compared to the material's volume measured in units of g/ml. The high-density value indicates a compact product. Low Kamba density will affect the size and cost of shipping, which is considered inefficient for producers and consumers. Black potato flour in this study has almost the same Kamba density, which was 0.66 ± 0.003 g/mL to 0.71 ± 0.008 g/mL. The Kamba density is also influenced by the sieve size used during flour making.

Functional Characteristics

Black potato flour originating from several locations in East Java has different functional characteristics, as presented in Table 3.

Water absorption is one parameter that shows the ability of a material to draw water around it (Singh, 2001). The value of water absorption from black potato flour in this study is almost the same compared to soybean flour (2.17 g/g) yet lower than taro flour (2.7 to 3.5 g/g) (Singh, 2001; Kaur et al., 2011). Water absorption of black potato flour is still relatively low and far below the value of water absorption of wheat flour. Water absorption is influenced by protein content. The higher the protein level, the more it can absorb water. Carbohydrates and proteins can influence water absorption. The presence of amylose can also affect water absorption. Water absorption capacity is critical to study because it can affect the ease of flour dough to be homogeneous when mixed with water. Tam et al. (2004) confirmed that flour having high water absorption tends to be easier to homogenize.

Oil absorption in black potato flours from the samples was almost the same, around 1 g/g. The oil absorption of black potato is also lower than that of wheat (1.46 g/g), *gembili* (1.62 g/g), and taro (2.4 g/g) (Ariyanti et al., 2014; Chandra et al., 2014; Richana et al., 2004). Oil absorption is the ability of flour to bind oil when interacting with oil. The protein content of the material strongly influences the nature of oil absorption. Oil absorption occurs when oil or fat binds to non-polar side chains of protein. Oil absorption is caused by physical oil trapping with capillary forces and protein hydrophobicity. Good oil absorption can improve the flavor and mouthfeel of food (Aini et al., 2016).

Swelling properties are the ability of starch to expand in water. Swelling properties are highly related to amylose content and starch properties (Blazek et al., 2008). The swelling of starch is related to water absorption into starch granules (Baile et al., 2002). After the gelatinization process, the hydrogen bonds between the starch molecules are cut off and replaced by hydrogen bonds with water. This causes gelatinized starch and starch granules to expand. The swelling process is due to the amount of water absorbed into the starch granules, which then expands and causes swelling properties to increase. Based on Table 3, black potato starch has lower swelling properties (5.38 to 9.12 g/g) than wheat flour (11 to 18 g/g) (Fu, 2017). It is supported by Table 4 correlation analysis that the swelling properties have a higher correlation to protein content than the amylose content. Nikolić et al. (2021) also stated that the lower amylose content would result in higher swelling properties.

A gel is the result of intermolecular interactions involving amylose and amylopectin. Gel formation occurs in the gelatinization mechanism. The measurement of gel consistency is carried out based on starch gelatinized under alkaline conditions and then cooled at room temperature (Perez and Juliano, 1978). The strength of the gel determines the texture and cooking quality, which will determine the quality of the overall food product (Yoenyongbuddhagal et al., 2002). This study's gel consistency in black potatoes ranges from 10 to 12 cm. The consistency of this gel is lower than the gel formed from rice flour, which is 20 cm (Lu et al., 2011). According to Masniawati et al. (2013), amylose content of around 25% will produce a hard gel. Low amylose content will produce a softer gel texture (Copeland et al., 2009).

Table 2. The physical characteristics of black potato flour from several locations in East Java

Characteristics	Begal Village	Sunthi Village	Kopenan Forest
Color (L)	74.03±0.11[a]	68.6 ±0.34[c]	70.4± 0.26[b]
Yield (%)	25.38[a]	18.31[c]	19.27[b]
Kamba density (g/mL)	0.69 ± 0.002[b]	0.66 ± 0.008[a]	0.66 ± 0.003[c]

Note: Values are expressed as mean ±SD. Means having different letters within the same row differs significantly at p ≤0.05

Table 3. The functional characteristics of black potato flour in several locations in East Java

Characteristics	Begal Village	Sunthi Village	Kopenan Forest
Water absorption (g/g)	1.92±0.05[b]	2.25±0.02[a]	2.21±0.05[a]
Oil absorption (g/g)	1.01±0.07[a]	1.04±0.05[a]	1.10±0.02[a]
Swelling properties *(g/g)*	5.38±0.49[c]	6.44±0.39[b]	9.12±0.24[a]
Gel consistency (cm)	10.8±0.45[b]	11.6±0.34[ab]	12.3±0.85[a]
Solubility index (%)	2.47±0.06[c]	3.55±0.13[b]	3.19±0.11[a]

Note: Values are expressed as mean ±SD. Means having different letters within the same row differs significantly at p ≤0.05

Table 4. The correlation coefficient between black potato flour attributes

	Moisture	Ash	Amylose	Fat	Protein	Starch	Phenolic	WAI	SP	SI	GC	Color
Moisture	1											
Ash	-0.822	1										
Amylose	0.979	-0.920	1									
Fat	0.577	-0.939	0.730	1								
Protein	-.999*	0.841	-0.986	-0.604	1							
Starch	0.979	-0.921	1.000**	0.731	-0.985	1						
Phenolic	-0.985	0.907	-.999*	-0.707	0.991	-.999*	1					
WAI	-0.989	0.899	-.999*	-0.693	0.993	-.999*	1.000*	1				
SP	-0.741	0.227	-0.590	0.121	0.718	-0.589	0.617	0.631	1			
SI	-0.934	0.971	-0.987	-0.830	0.946	-0.987	0.981	0.977	0.453	1		
GC	-0.899	0.490	-0.792	-0.161	0.884	-0.791	0.812	0.823	0.960	0.684	1	
Color	0.925	-0.977	0.983	0.844	-0.937	0.983	-0.976	-0.972	-0.431	-1.000*	-0.665	1

Table 5. Correlation loadings for 3 black potato flour from different origins and 13 physicochemical characteristics

Variable	Color	Yield	Kamba Density	Moisture	Ash	Amylose	Fat	Protein	Starch	Phenolic	WAI	OAI	SP	SI	GC
PC1	**-0.282**	**-0.292**	-0.008	**-0.29**	**0.259**	**-0.291**	-0.196	**0.291**	**-0.291**	**0.292**	**0.292**	0.206	0.191	**0.284**	**0.246**
PC2	0.146	0.02	**-0.55**	-0.066	**-0.256**	0.045	**0.408**	0.048	0.047	-0.027	-0.017	**0.39**	**0.416**	-0.133	**0.299**

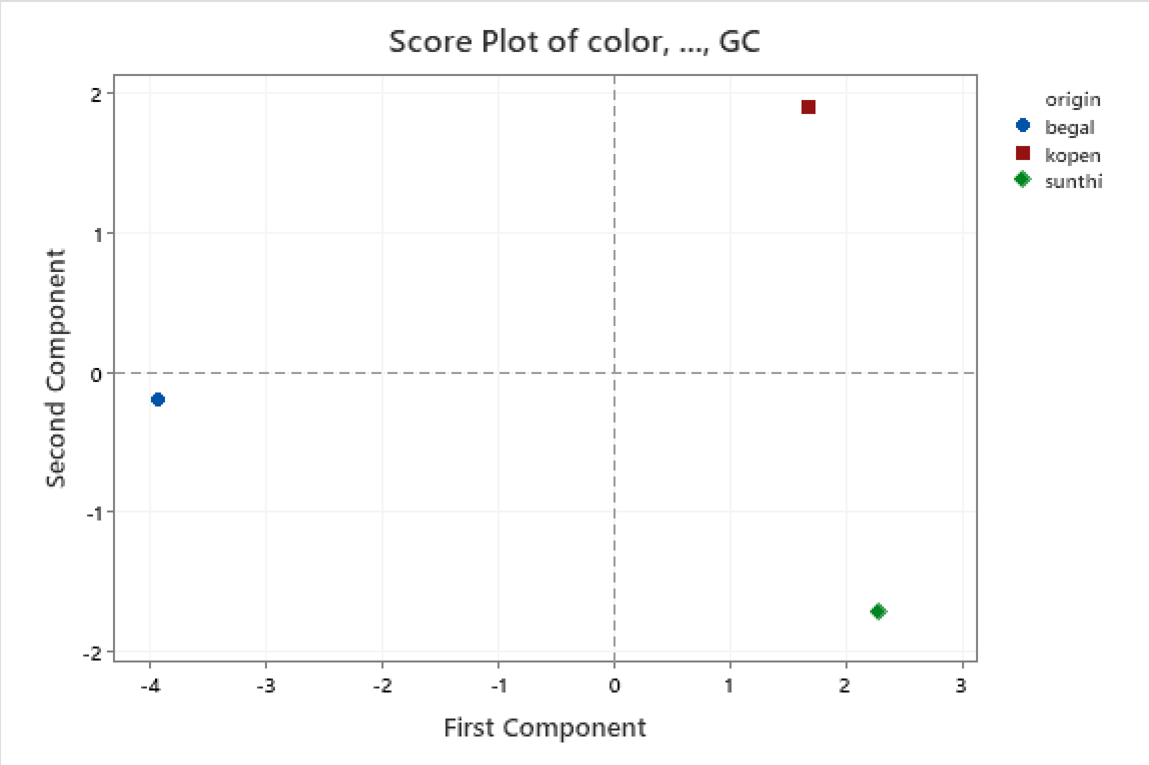

Figure 1. Scoreplot for PC1 vs PC2

A solubility index shows the ability of a solid to dissolve in water. The solubility index can be influenced by amylose and fat. Proteins and carbohydrates can increase water absorption due to their hydrophilic properties. The higher the protein content, the higher the solubility index will be. The solubility of flour in water is strongly influenced by the fraction of amylose released from starch. Increased water absorption is usually followed by an increase in water solubility index (Anggraeni and Yuwono, 2014). The use of flour with a high solubility index needs to be adjusted to the product's characteristics, for example, in baby food, food powder, cake mixes, and pudding (Habibah et al., 2018). The solubility index of black potato flour used in this study ranged from 2.47 to 3.5%.

Correlation and Principal Component Analysis

Table 4 illustrates the correlation coefficients between the physicochemical properties of black potato flour from several locations in East Java. Several characteristics are found to be highly correlated to each other. The water absorption index recorded the highest negative and positive correlation with the amylose, starch, and phenolic content. The colour was expected to have a high correlation with the phenolic content. But Table 2 showed that colour was highly positively and negatively correlated with almost all chemical properties. This might be due to the addition of sodium metabisulphite during the processing of the black potato flour. Therefore, phenolic content was not the only contributing factor to the colour characteristics. The table also represented that the flour's functional properties (water absorption index, swelling properties, solubility index, and gel consistency) were positively correlated with protein content but negatively correlated with the amylose and starch content. This might be during the flour processing did not involve gelatinization, so the solubility of native starch is still low.

In the PCA, the two first principal components (PCs) explained 100% of the real differences between the three samples (Table 6).

Table 6. Explained variance

	PC1	PC2
Eigenvalue	11.695	3.305
Proportion	0.780	0.220
Cumulative	0.780	1.000

The first PC accounted for 78% of the differences observed, and the second PC was alleged for the 22 differences between the samples. Table 5 shows that the first PC was physical characteristics (i.e. colour, yield), chemical characteristics (i.e. moisture, ash, amylose protein, starch, phenolic content), and functional properties (i.e. water absorption index, solubility index, and gel consistency). The second PC was physical characteristics (i.e. Kamba density), chemical properties (i.e. ash and fat content), and functional properties (i.e. oil absorption index, swelling properties, and gel consistency). Figure 1 shows that the score plot of the three samples was separated between the two principal component scores. The black potato flour from Dusun Begale was negatively loading on PC 1; the other two samples were positively loading on PC 1. Furthermore, the sample originating from Kopen was positively loading on PC2, but from Dusun Sunthi was negatively loading on PC2.

Conclusion

According to gel consistency, water absorption index, oil absorption index, and swelling properties, it can be hypothesized that *C. tuberosus* can be homogenous in the dough mixture. The flour has a relatively high amylose content and produces a soft gel that can be used to substitute rice flour in making rice paper and filler in various kinds of food. Further analysis is needed to characterize more physicochemical properties of this flour. Some high correlations (positively or negatively) were found between the black potato flours' chemical, physical, and functional properties. One high correlation was the functional properties (water absorption index) with three chemical properties, namely starch, amylose, and total phenolic content. The PCA analysis also found that based on the properties, the three samples were located differently in the score plot. Explained variance also found that the two first PCs were the giving factor for 100% of the differences. The difference between black Several high correlations was found between characteristics of the black potato flours. One high correlation was the water absorption index with starch, amylose, and total phenolic content. The PCA analysis also found that the three samples were loading differently in the score plot. Two first PC was the contributing factor for 100% of the differences. The difference between black potato flour from Begal with the two other samples was categorized by the first PC, but the sample from Sunthi and Kopen was characterized by PC2.

Declarations

Conflict of interests The authors declare no competing interests.

References

Aboubakar, Njintang, Y. N., Scher, J., and Mbofung, C. M. F. (2008) 'Physicochemical, thermal properties, and microstructure of six varieties of taro (*Colocasia esculenta* L. Schott) flours and starches', *Journal of Food Engineering*, 86(2), pp. 294–305

Adebowale, Y., Adeyemi, A., and Oshodi, A. A. (2005) 'Variability in the physicochemical, nutritional, and antinutritional attributes of six *Mucuna* species', *Food Chemistry*, 89(1), pp. 37–48

Aini, N., Wijonarko, G., and Sustriawan, B. (2016) 'Sifat fisik, kimia, dan fungsional tepung jagung yang diproses melalui fermentasi (Physical, chemical, and functional properties of corn flour processed by fermentation)', *Jurnal Agritech*, 36(2), pp. 160-169 [In Indonesian]

Anggraeni, Y. P., and Yuwono, S. S. (2014) 'Pengaruh fermentasi alami pada chips ubi jalar (*Ipomoea Batatas*) terhadap sifat fisik tepung ubi jalar terfermentasi (Effect of natural fermentation on sweet potato chips (*Ipomoea batatas*) on physical properties of fermented sweet potato flour)', *Jurnal Pangan dan Agroindustri*, 2(2), pp. 59-69 [In Indonesian]

AOAC. (2005) O*fficial Methods of Analysis of the AOAC International, 16th 432 ed., supplement 1998*. Washington, DC: AOAC

Ariyanti, D., Budiyati, C. S., and Kumoro, A. C. (2014) 'Modifikasi tepung umbi talas Bogor (*Colocasia esculentum* (L) Schott) dengan teknik oksidasi sebagai bahan pangan pengganti tepung terigu (Modification of Bogor taro tuber flour (*Colocasia esculentum* (L) Schott) with oxidation technique as a substitute for wheat flour)', *Jurnal Reaktor*, 15(1), pp. 1-9 [In Indonesian]

Aryee, F. N. A., Oduro, I., Ellis, W. O., and Afuakwa, J. J. (2006) 'The physicochemical properties of flour samples from the roots of 31 varieties of cassava', *Food Control*, 17(11), pp. 916–922

Baille, W. E., Malveau, C., Zhu, X. X., and Marchessault, R. H. (2002) 'NMR imaging of high-amylose starch tablets. 1. swelling and water uptake', *Biomacromolecules*, 3(1), pp. 214–218

Blazek, J., and Copeland, L. (2008) 'Pasting and swelling properties of wheat flour and starch in relation to amylose content', *Carbohydrate Polymers*, 71(3), pp. 380–387

Burrell, M. M. (1984) 'Inhibition of browning, phenoxyacetic acids and phenolic metabolism in potato tuber discs: a model system to study chemicals that control common scab', *Plant Pathology*, 33(3), pp. 325–336

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(6), pp. 3681-3688

Chandrasekara, A., and Kumar, T. J. (2016) 'Roots and tuber crops as functional foods: a review on phytochemical constituents and their potential health benefits', *International Journal of Food Science*, 2016, pp. 1–15

Clegg, K. M. (1956) 'The application of the anthrone reagent to the estimation of starch in cereals', *Journal of the Science of Food and Agriculture*, 7(1), pp. 40–44

Copeland, L., Blazek, J., Salman, H., and Tang, M. C. (2009) 'Form and functionality of starch', *Food Hydrocolloids*, 23(6), pp. 1527–1534

Craig, S. A., Maningat, C. C., Seib, P. A., and Hoseney, R. C. (1989) 'Starch paste clarity', *Cereal chemistry*, 66(3), pp. 173-182

Dansby, M. Y., and Bovell-Benjamin, A. C. (2003) 'Production and proximate composition of a hydroponic sweet potato flour during extended storage', *Journal of Food Processing and Preservation*, 27(2), pp. 153–164

Enyiukwu, D. N., Awurum, A. N., and Nwaneri, J. A. (2014) 'Potentials of hausa potato (*Solenostemon rotundifolius* (Poir.) J. K. Morton and management of its tuber rot in Nigeria', *Greener Journal of Agronomy, Forestry and Horticulture*, 2(2), pp. 27–37

Fu, B. X., Wang, K., and Dupuis, B. (2017) 'Predicting water absorption of wheat flour using high shear-based GlutoPeak test', *Journal of Cereal Science*, 76, pp. 116–121

Habibah, F., Yasni, S., and Yuliani, S. (2018) 'Karakteristik fisikokimia dan fungsional pati hidrotermal ubi jalar ungu (Physicochemical and functional characteristics of purple sweet potato hydrothermal starch)', *Jurnal Teknologi Dan Industri Pangan*, 29(1), pp. 69–76 [In Indonesian]

Hsum, Y. P., Yew, W. T., Hong, P. L. V., Soo, K. K., Hoon, L. S., Chieng, Y. C., and Mooi, L. Y. (2010) 'Cancer chemopreventive activity of maslinic acid: Suppression of COX-2 expression and inhibition of NF-κB and AP-1 activation in raji cells', *Planta Medica*, 77(2), pp. 152–157

Kamal, M. S., Islam, M. N., and Aziz, M. G. (2014) 'Effect of sweet potato flour of two local varieties on quality of breads', *Journal of the Bangladesh Agricultural University*, 11(2), pp. 301–306

Kaur, M., Kaushal, P., and Sandhu, K. S. (2011) 'Studies on physicochemical and pasting properties of Taro (*Colocasia esculenta L.*) flour in comparison with a cereal, tuber and legume flour', *Journal of Food Science and Technology*, 50(1), pp. 94–100

Laeliocattleya, R. A., Estiasih, T., Griselda, G., and Muchlisyiyah, J. (2018) 'The bioactive compounds and antioxidant activity of ethanol and ethyl ecetate extracts of Candi Banana (*Musa paradisiaca*)', *IOP Conference Series: Earth and Environmental Science*, 131, pp. 1-5

Lalel, H. J. D., Abidin, Z., and Jutomo, L. (2009) 'Sifat fisiko kimia beras merah gogo lokal Ende (The Physico-chemical properties of local Ende high land brown rice)', *Jurnal Teknologi dan Industri Pangan*, 20(2), 109-116 [In Indonesian]

Leach, V. H. W., Schoch, T. J., and Chessman, E. F. (1961) 'Adsorption von Alkalien durch das Stärkekorn' *Starch - Stärke*, 13(6), pp. 200–203

Lim, Y. M. (2002) 'Anti-tumour promoting activity of selected Malaysian vegetables and fruits, and identification of anti-tumour promoting and antioxidant compounds from *Coleus tuberosus*, Benth (ubi kemili). Dissertation. Universiti Putra Malaysia

Lu, Z. H., Li, L. T., Min, W. H., Wang, F., and Tatsumi, E. (2005) 'The effects of natural fermentation on the physical properties of rice flour and the rheological characteristics of rice noodles', *International Journal of Food Science and Technology*, 40(9), pp. 985–992

Mandasari, R., Amanto, B. S., and Ridwan, A. (2015) 'Kajian karakteristik fisik, kimia, fisikokimia dan sensori tepung kentang hitam (*Coleus tuberosus*) termodifikasi menggunakan asam laktat (Study of physical, chemical, physicochemical characteristics and sensory properties black potato (*Coleus tuberosus*) flour modified by lactic acid solution)', *Jurnal Teknosains Pangan*, 4(3), pp. 1-15 [In Indonesian]

Masniawati, A., Johannes, E., Latunra A. I., Paelongan, N. (2013) 'Karakterisasi sifat fisikokimia beras merah pada beberapa sentra produksi beras di Sulawesi Selatan (Characterization of physicochemical properties of brown rice in several rice production centers in South Sulawesi)', Repository Universitas Hassanudin, Makassar [In Indonesian]

Muchtadi, T. R. (1997) *Teknologi Proses Pengolahan Pangan* (*Food Processing Technology*). Departemen Pendidikan dan Kebudayaan Direktorat Jenderal Pendidikan Tinggi Pusat Antar Universitas Pangan dan Gizi. IPB. Bogor [In Indonesian]

Mukherjee, A., Vimala, B., Nambisan, B., Chakrabarti, S. K., George, J., and Gowda, H. (2015)

'Underutilized tropical tuber crops with hidden treasure of food, nutrition, and medicine', *International Journal of Tropical Agriculture*, 33(4), pp. 3803-3815

Naczk, M., and Shahidi, F. (2019) *Phenolics in Food and Nutraceuticals*. Boca Raton: CRC Press.

Niba, L. L., Bokanga, M. M., Jackson, F. L., Schlimme, D. S., and Li, B. W. (2002) 'Physicochemical properties and starch granular characteristics of flour from various *Manihot esculenta* (Cassava) Genotypes', *Journal of Food Science*, 67(5), pp. 1701–1705

Nikolić, V., Simić, M., Kandić, V., Dodevska, M., Titan, P., Dodig, D., and Žilić, S. (2021) 'Pasting properties and the baking functionality of whole-grain wheat flour with different amylose and dietary fibers content', *Journal of Food Processing and Preservation*, e15805.

Noman, A. S. M., Hoque, M. A., Haque, M. M., Pervin, F., and Karim, M. R. (2007) 'Nutritional and anti-nutritional components in *Pachyrhizus erosus L.* tuber', *Food Chemistry*, 102(4), pp. 1112–1118

Nugraheni, M., Hamidah, S., & Windarwati, W. (2015) 'Effect of *Coleus tuberosus* flour high resistant starch consumption in glucose, lipid, digest and short chain fatty acid profile in normal rats', *Advance Journal of Food Science and Technology*, 8(12), 844–852

Nugraheni, M., Santoso, U., and Windarwati (2014) 'Effect of consumption of *Coleus tuberosus* on the lipid profile of Alloxan-induced diabetic rats', *Advance Journal of Food Science and Technology*, 6(2), 159–166

Perez, C. M., and Juliano, B. O. (1978) 'Modification of the simplified amylose test for milled rice', Starch - Stärke, 30(12), pp. 424–426

Quettier-Deleu, C., Gressier, B., Vasseur, J., Dine, T., Brunet, C., Luyckx, M., Cazin, J. C., Bailleul, F., and Trotin, F. (2000) 'Phenolic compounds and antioxidant activities of buckwheat (*Fagopyrum esculentum Moench*) hulls and flour', *Journal of Ethnopharmacology*, 72(1-2), pp. 35–42

Radley, J. A. (1976) *Industrial Uses of Starch and its Derivatives.* Dordrecht: Springer

Richana, N., and Sunarti, T. C. (2004) 'Karakterisasi sifat fisikokimia tepung umbi dan tepung pati dari umbi ganyong, suweg, ubi kelapa dan gembili (Characterization of physicochemical properties of tuber flour and starch from canna, suweg, coconut and gembili tubers)', *Jurnal pascapanen*, 1(1), pp. 29-37 [In Indonesian]

Sánchez-Mariñez, R. I., Cortez-Rocha, M. O., Ortega-Dorame, F., Morales-Valdes, M., and Silveira, M. I. (1997) 'End-use quality of flour from *Rhyzopertha dominica* infested wheat', *Cereal Chemistry Journal*, 74(4), pp. 481–483

Singh, U. (2001) 'Functional properties of grain legume flours', *Journal of Food Science and Technology*, 38(3), pp. 191–199

Singh, U., and B Singh. (1991) 'Functional properties of sorghum-peanut composite flour', *Cereal Chemistry*, 68 (5), pp. 460-463

SNI. (2011) Indonesia National Standard 2011. National Standardization Agency of Indonesia [In Indonesian]

Sreerama, Y. N., Sashikala, V. B., and Pratape, V. M. (2012) 'Phenolic compounds in cowpea and horse gram flours in comparison to chickpea flour: Evaluation of their antioxidant and enzyme inhibitory properties associated with hyperglycemia and hypertension', *Food Chemistry*, 133(1), pp. 156–162

Susilawati, Nurdjanah, S., and Putri, S. (2012) 'Karakteristik sifat fisik dan kimia ubi kayu (*Manihot esculenta*) berdasarkan lokasi penanaman dan umur panen berbeda (Characteristics of physical and chemical properties of cassava (*Manihot esculenta*) based on different planting locations and harvest ages)', *Jurnal Teknologi & Industri Hasil Pertanian*, *13*(2), 59-72 [In Indonesian]

Syarif, F. (2015) 'Tanggap beberapa aksesi kentang hitam (*Plectranthus rotundifolius*) terhadap tingkat pemberian air pada fase pertumbuhan dan produksi (Response of several black potato (*Plectranthus rotundifolius*) accession against watering levels on growth and production phase)', *Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia*, 1(6), pp. 1536-1541[In Indonesian]

Taggart, P. (2004). *Starch as an ingredient: manufacture and applications*. UK: National Starch and Chemical.

Tam, L. M., Corke, H., Tan, W. T., Li, J., and Collado, L. S. (2004) 'Production of bihon-type noodles from maize starch differing in amylose content', *Cereal Chemistry Journal*, 81(4), pp. 475–480

Tsaalitsati, I. I., Ishartani, D., and Kawiji, K. (2016) 'Kajian sifat fisik, kimia, dan fungsional tepung ubi jalar oranye (*Ipomoea batatas* (L.) lam.) varietas beta 2 dengan pengaruh perlakuan pengupasan umbi (Study of physical, chemical, and functional properties of orange sweet potato flour (*Ipomoea batatas* (L.) lam.) beta 2 variety with the effect of tuber stripping treatment)', *Jurnal Teknosains Pangan*, 5(2), pp. 19-27 [In Indonesian]

Ukpabi, U. J., Oti, E., and Ogbogu, N. J. (2011) 'Culinary and sensory characteristics of Hausa potato (*Solenostemon rotundifolius*) and Livingstone potato (*Plectranthus esculentus*) tubers in Nigeria', *Journal of Stored Products and Postharvest Research*, 2(16), pp. 301-304

Williams, P. C. (1963) 'Relationship between consistency of wheat grain and flour diastatic activity', *Nature*, 200, pp. 172–173

Yoenyongbuddhagal, S., and Noomhorm, A. (2002) 'Effect of physicochemical properties of high-amylose Thai rice flours on vermicelli quality', *Cereal Chemistry Journal*, 79(4), pp. 481–485

Yulita, K. S., Ahmad, F., Martanti, D., Poerba, Y. S., and Herlina (2014) ‘Analisis keragaman genetik kentang hitam (*Plectranthus rotundifolius* (Poiret) Sprengel) berdasarkan marka ISSR Dan RAPD (Analyisis of genetic variations of ‘kentang hitam (Genetic diversity analysis of black potato (*Plectranthus rotundifolius* (Poiret) Sprengel) based on ISSR and RAPD (Analysis of genetic variations of black potato) markers)' *Plectranthus rotundifolius* (Poiret) sprengel based on ISSR and RAPD marker)’, *Berita Biologi*, 13(2), pp. 127-135 [In Indonesian]