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Physicochemical characteristics of tannia cocoyam (*Xanthosoma sagittifolium*) corm flour compared to flours and starches of other grains and tubers

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Abstract

Tannia cocoyam corm is a less popular pantropical carbohydrate source, whereas it has the potential to support food and nutrition security, especially in dry areas. Processing tannia cocoyam corm into flour can increase its use in various food products. This study aimed to determine the yield, nutrition, color, tap bulk density, water absorption capacity (WAC), oil absorption capacity (OAC), swelling capacity, and emulsion activity and stability of tannia cocoyam corm flour compared to sago starch, cassava flour and starch, mung bean starch, corn starch, wheat flour, rice and glutinous rice flours, and potato flour. The significant characteristics of tannia cocoyam corm flour were rather low in calories (dry basis), relatively high in WAC and swelling capacity, low in OAC, and showed emulsion activity and stability. Based on these data, it is suitable for use in mixed and processed food products that require juicy, elastic, and volume expansion characteristics; recommended for food products that are lower in calories and oil content; and can also help to maintain viscosity and form emulsions.

1. Introduction

The food self-sufficiency program in Indonesia since 1959 has changed the food choices of the Indonesian people to this day. The program aimed to achieve food security with a focus on wetland farming, that is rice fields. Unfortunately, this program paid less attention to dryland agriculture. The impact that has occurred so far is the reduced diversity of food that has the potential to threaten nutritional security, especially for urban communities. Urban communities often have more limited access to dietary diversity than rural communities that have access to fields or even forests. As is known, dietary diversity is one of the key elements to meet all nutritional needs (Solomon *et al.*, 2017).

The tannia cocoyam (*Xanthosoma sagittifolium*) plant originated from tropical America but has long been known in Indonesia. Cocoyam corm is one of the important pantropical root vegetables that support food security and nutrition, especially in dry areas, although it is generally not the main food of choice (Lim, 2015; Boakye *et al.*, 2018; Wada *et al.*, 2019). Nowadays, Indonesian people prefer rice over other carbohydrate sources, which have more choices of side dishes and are more in line with current culinary developments. This condition not only threatens food diversification and nutritional security but also threatens biodiversity. For example, farmers in Wonokitri, East Java, prefer to plant crops that have higher economic value than tannia cocoyam, such as potatoes, cabbage, and leeks, while tannia cocoyam is often only a side crop in the fields (Shobirin, 2021).

Compared to taro (*Colocasia esculenta*), tannia cocoyam corm has lower oxalate levels (Lim, 2015; Markusse *et al.*, 2018). This means the Javanese cocoyam corms do not irritate the skin and oral mucosa, although Ukom and Okerue (2018) reported that cocoyam corms in Nigeria caused an acrid taste and irritated the mouth and throat. However, the popularity of this root vegetable is inferior to potato, sweet potato, and cassava which are more commonly cultivated and consumed in Indonesia. Rural people usually steam the corm for consumption, but this method is not preferred by urban communities because the corms are a little slimy and they are not used to the taste. This is related to the mucilage content that is characteristic of corms from the arum family, including tannia cocoyam (Ashogbon, 2022).

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Cocoyam corm is also processed into chips, although quite a lot of people cannot tell the difference between tannia cocoyam and taro, both of which are often considered the same and cause irritation. This is what makes tannia cocoyam difficult to become popular.

Carbohydrate sources such as cocoyam corm can be processed into flour therefore it is easily mixed and made into several types of final products, enriched with nutrients, thus prolonging its shelf life compared to fresh commodities (Antarlina *et al.*, 2021; Ogunka *et al.*, 2021). Tannia cocoyam flour has been used as a flour substitute in bakery and pasta products (Ronie *et al.*, 2021), in meat analogues (Lindriati *et al.*, 2020), food bars (Rejeki *et al.*, 2019), or even composite flour (Olaoye and Obidegwe, 2018). Composite flours are produced for economic, nutritional, and health reasons, for supply chain sustainability, or to enhance consumer tastes (Chandra *et al.*, 2015; Amin *et al.*, 2021). Flour is also more easily modified to change its physicochemical characteristics such as water solubility and viscosity (Antarlina *et al.*, 2021).

There have been many research studies related to tannia cocoyam corm flour, especially the analysis of its nutritional content and its use in various food products. It was found that cocoyam corm flour was less successful in substituting wheat flour for bread, thus it was recommended to use it for biscuits (Ronie *et al.*, 2021). The question that various research still fails to answer is, should we process cocoyam corm flour thus it can be used as a substitute for wheat flour in products that we are already familiar with, or is it better to develop food products that match the characteristics of cocoyam corm flour instead? To answer this question, we must understand the physicochemical characteristics of cocoyam flour compared to other flour.

This study compares the physicochemical characteristics of tannia cocoyam corm flour with other flour and starches with the aim of providing an overview of its potential uses for various flour or starch-based food products. Differences in physicochemical characteristics have an important effect on the characteristics of the final product (Amin *et al.*, 2021) and its nutritional value, among others related to the speed of digestion (Noorfarahzilah *et al.*, 2020). The data provided in this study relates to the economic potential of tannia cocoyam corm flour production, followed by its nutritional and physicochemical analysis compared to various other flours and starch. Through this research, it is hoped that other research can be developed to examine the use of tannia cocoyam corm flour, either as ready-to-eat or intermediate food products.

2. Materials and methods

2.1 Materials

Tannia cocoyam corms were obtained from traditional retail markets in Wonokitri (Pasuruan Regency) and modern retail markets in Surabaya, both in East Java, Indonesia. Each was made into flour and coded as XF1 and XF2, respectively. Sago starch (SS), tapioca starch brand A (TS1) and brand B (TS2), mung bean starch (MS), corn starch (CS), wheat flour (WF), rice flour (RF), white glutinous rice flour (GF), and palm cooking oil for analysis were all produced and packaged in Indonesia. Cassava flour (CF), potato flour (PF), Barium Sulfate Anhydrous, and distilled water were kindly provided by the Chemistry and Biochemistry Laboratory, Department of Food Technology, Universitas Ciputra Surabaya.

2.2 Flour making and yield analysis

Tannia cocoyam corms were stored at ambient temperature in an open container before processing. Dirty corms were weighed (digital kitchen scale Taffware Z2S, IDN), washed, and air-dried. The clean corms were weighed, peeled, and weighed again, sliced in 1 mm thickness, dried at 60°C for about 20 hrs (digital oven Memmert UF55, DEU), ground (herb grinder Fomac FCT-Z500, IDN), sieved (80 mesh), and weighed. Cocoyam corm flour was then stored in double PE (polyethylene) plastic bags at ambient temperature before analysis.

2.3 Proximate analysis and calory

Nine samples (XF1, XF2, SS, TS1, MS, CS, WF, RF and GF) were analyzed for their moisture, ash, protein, and fat content using SNI 01-2891-1992 method by the National Standardization Agency of Indonesia (Badan Standardisasi Nasional, 1992). Carbohydrate content was calculated by difference. The calorie was calculated by multiplying the fat, protein, and carbohydrate content with Atwater Factor (9 kcal, 4 kcal and 4 kcal per g, respectively).

2.4 Whiteness

The CIE L*a*b* (CIELAB) color system was used to measure the whiteness of all 12 flour and starch samples (colorimeter CHNSpec CS-10, CHN) in triplicate (Melese *et al.*, 2021). The colorimeter was calibrated using the white and black color standards on the instrument. Barium sulfate was used for white color comparison (Höpe, 2014). Whiteness was calculated by the following formula:

$$\text{Whiteness} = 100 - [(100-L)2 + a2 + b2)]^{½}$$

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2.5 Tap bulk density

The tap bulk density method was modified by Ogunka *et al.* (2021). A total of 5 g sample was weighed (technical electronic balance Shimadzu BL-2200H, PHL) and carefully transferred into a 50 mL measuring cylinder. It was gently tapped until the volume was no longer visually reduced. Tap Bulk density was calculated by dividing sample weight in grams (w) by the final volume in mL (v), as the following formula:

$$\text{Tap bulk density} = w/v$$

2.6 Water absorption capacity and oil absorption capacity

WAC and OAC methods were performed following Chandra *et al.* (2015) and Amin *et al.* (2021) with modification. A total of 5 mL distilled water or cooking oil was put into a 15 mL centrifuge tube along with a 1.2500 g sample (analytical electronic balance Shimadzu ATX224, PHL) and then homogenized (vortex mixer Thermo Scientific 88880018, DEU) at 2500 rpm for 1 min. After resting for 30 mins at room temperature, the mixture was centrifuged (Nüve NF800, TUR) at 3700 rpm for 30 mins. Any remaining water or oil was carefully removed. WAC and OAC were expressed by dividing the weight of the residue that absorbs water or oil (w2) by the initial weight of the sample (w1) in grams as follows:

$$\text{WAC or OAC} = w2/w1$$

2.7 Swelling capacity

The swelling capacity method was performed following Chandra *et al.* (2015) with modification. The sample was put into a 15 mL centrifuge tube while being tapped until it solidified and a volume of 2 mL was obtained. Distilled water was added to obtain a total volume of 10 mL then shaken manually for 1 min until mixed. After being allowed to stand for 2 mins, the sample was again shaken manually and allowed to stand for 8 mins. The percentage swelling capacity was calculated by dividing the expansion volume (v2) by the initial sample volume (v1), as follows:

$$\text{Swelling capacity} = (v2/v1) \times 100$$

2.8 Emulsion activity and stability

Emulsion activity and stability methods were performed following Chandra *et al.* (2015) with modification. A total of 0.5 g sample was weighed using a technical electronic balance in a 15 mL centrifuge tube. A total of 5 mL distilled water and 5 mL cooking oil were put into the tube and stirred manually until mixed well with the sample. The mixture was then centrifuged at 3000 rpm for 5 mins. The percentage of emulsion activity was obtained from the height of the emulsion layer (h2) formed divided by the total height of the mixture (h1), as follows:

$$\text{Emulsion activity} = (h2/h1) \times 100$$

The centrifuge tube with the sample mixture was then heated (PolyScience Waterbath SH28L, USA) at 80°C for 30 mins, cooled using running water for 15 mins, then centrifuged at 3000 rpm for 15 mins. The percentage of emulsion stability was measured by the height of the remaining emulsion layer (h3) divided by the total height of the mixture (h1), as follows:

$$\text{Emulsion stability} = (h3/h1) \times 100$$

3. Results and discussion

3.1 Yield analysis

Yield information is generally used for purchasing and production planning. In this research, tannia cocoyam corms were purchased at two different locations to calculate the estimated yield of cocoyam corm flour as shown in Table 1. It was found that there was no difference in yield between cocoyam obtained from retail markets at traditional markets in Wonokitri (XF1) and modern markets in Surabaya (XF2). Yields may differ if corms were purchased at a wholesale market or from the farmer. In the wholesale market, the buyer cannot choose the best corms to buy as in the retail market. In addition, corms in the wholesale market are still relatively fresh and wet, which can increase the weight of the dirt attached to the corms. Corms with damaged parts may also be more numerous which can add to the weight of the unusable parts.

Table 1. The yield of tannia cocoyam corm and flour from markets in Wonokitri and Surabaya.

Parameters	Yields (% w/w)	
	XF1	XF2
Dirt	1.07±0.30	0.64±0.01
Skin and damaged parts	12.66±1.78	11.37±1.42
Dried chips	27.53±0.32	27.11±0.37
Flour passed through an 80-mesh sieve	24.74±1.83	25.01±1.81

Values are presented as mean±standard deviation, n = 2. The yield was calculated against the weight of a clean, unpeeled corm.

A flour yield of 20-25% was also observed when conducting previous research on seasoning blends from cocoyam flour (Minantyo *et al.*, 2017). Thus, it is safe to assume that the yield of tannia cocoyam corm flour is about 25% of its fresh corm weight.

3.2 Chemical composition and calorie

Proximate analysis was performed on five flour samples (XF1, XF2, WF, RF and GF) and four starch samples (SS, TS1, MS and CS). Table 2 shows the percentage of water content on a wet basis, while fat, protein, carbohydrates, and calories were calculated on a dry basis.

Moisture content data is needed by flour industries to find out whether their products meet the quality standard for sale. The maximum moisture content of flours set in standards by the National Standardization Agency of Indonesia is generally 13-14%. The longer flour products are stored, the water content will certainly increase, thus increasing the risk of contamination by microorganisms and insects. It also increases the cohesive forces between the particles, thereby reducing their flowability, lowering bulk density, and increasing the risk of caking during storage (Hasmadi, 2021).

Fat, protein, carbohydrate, and calorie content were calculated on a dry basis to better reflect the actual content without being affected by the moisture content differences of each sample. As expected, the carbohydrate contents of starch samples were significantly higher than that of flour, while the protein contents of starches were significantly lower, and the fat contents varied. The starch-making process seems to dissolve the protein content, but not the fat content.

The calorie data in Table 2 confirm that protein and fat also play an important role in contributing to the number of calories. Carbohydrate is often considered the main contributor to calories while the contribution of protein is often overlooked. On the other hand, starch content may support health, especially amylose which can turn into resistant starch after being processed into food products (Cai *et al.*, 2021).

XF1 and XF2 cocoyam corm flour data showed higher protein content than starch samples (SS, TS1, MS, CS), but lower than cereal flours (WF, RF and GF). It also has the lowest dry basis calorie content compared to all other flour and starch samples. This finding needs to be further confirmed in future studies.

3.3 Whiteness and physicochemical characteristics

Color and physicochemical analyses were performed on seven flour samples (XF1, XF2, WF, RF, GF, CF and PF) and five starch samples (SS, TS1, TS2, MS and CS) in triplicate. Figure 1 shows the whiteness chart of the samples with Ba_2SO_4 as a comparison. Tap bulk density, WAC, OAC, expansion capacity, emulsion activity and emulsion stability are shown in Table 3.

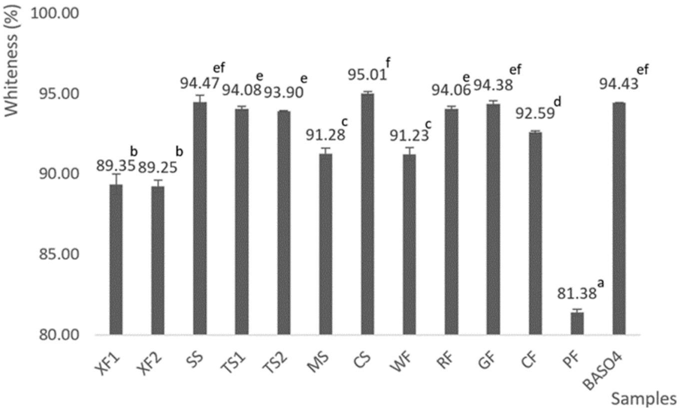

Figure 1. The whiteness of samples in percent with $BaSO_4$ as a comparison. Values with different superscripts are statistically significantly different ($p \leq 0.05$).

Cocoyam corm flour (XF1 and XF2) was made without treatment to maintain its white color in order that the original color can be known. Based on the data, cocoyam flour is only significantly whiter than visually yellowish potato flour. Whiteness is one indicator of the commercial quality of flour, although it may not have a real impact after being processed into food products. However, this indicator can be used by consumers as a

Table 2. Chemical composition and calorie.

Samples	Moisture content (% wb)	Fat content (% db)	Protein content (% db)	Carbohydrate content (% db)	Calorie per 100 g db (kcal)
XF1	8.26 ± 0.91^{ab}	0.17 ± 0.01^{ab}	4.22 ± 0.28^{b}	92.28 ± 0.44^{c}	387.52 ± 0.69^{a}
XF2	7.32 ± 0.83^{a}	0.21 ± 0.04^{ab}	5.09 ± 0.72^{b}	90.51 ± 0.70^{bc}	384.31 ± 0.21^{a}
SS	14.13 ± 0.54^{d}	0.65 ± 0.84^{ab}	0.33 ± 0.07^{a}	98.83 ± 0.83^{d}	402.48 ± 4.47^{b}
TS1	13.06 ± 0.14^{cd}	0.09 ± 0.00^{a}	0.26 ± 0.09^{a}	99.44 ± 0.06^{d}	399.63 ± 0.13^{b}
MS	13.85 ± 0.37^{cd}	0.06 ± 0.00^{a}	0.16 ± 0.05^{a}	99.45 ± 0.03^{d}	398.99 ± 0.07^{b}
CS	9.98 ± 2.80^{abc}	0.07 ± 0.01^{a}	0.48 ± 0.10^{a}	99.07 ± 0.41^{d}	398.80 ± 1.37^{b}
WF	13.05 ± 0.23^{cd}	1.32 ± 0.34^{b}	16.01 ± 1.47^{d}	82.05 ± 1.19^{a}	404.15 ± 1.92^{b}
RF	12.22 ± 0.06^{bcd}	0.15 ± 0.03^{ab}	10.53 ± 0.95^{c}	89.05 ± 1.01^{b}	399.67 ± 0.06^{b}
GF	12.13 ± 0.07^{bcd}	0.17 ± 0.01^{ab}	9.80 ± 0.65^{c}	89.74 ± 0.89^{bc}	399.64 ± 1.01^{b}

Values are presented as mean±standard deviation, n = 2. Values with different superscripts within the same column are statistically significantly different ($p \leq 0.05$). Percentage of moisture content on a wet basis (wb). The percentages of fat, protein, and carbohydrates as well as calories are calculated on a dry basis (db).

Table 3. Tap Bulk density, WAC, OAC, swelling capacity, emulsion activity and emulsion stability.

Samples	Tap Bulk Density (g/mL)	Water Absorption Capacity (%)	Oil Absorption Capacity (%)	Swelling Capacity (%)	Emulsion Activity (%)	Emulsion Stability (%)
XF1	0.85 ± 0.01^{g}	2.19 ± 0.02^{e}	1.54 ± 0.03^{abc}	316.67 ± 14.43^{de}	2.59 ± 0.04^{a}	1.01 ± 0.01^{a}
XF2	0.81 ± 0.02^{f}	1.77 ± 0.16^{abc}	1.50 ± 0.04^{ab}	308.33 ± 14.43^{d}	3.43 ± 2.12^{a}	1.03 ± 0.02^{a}
SS	0.68 ± 0.01^{e}	1.57 ± 0.02^{ab}	1.39 ± 0.11^{a}	183.33 ± 28.87^{c}	-	-
TS1	0.55 ± 0.01^{a}	1.54 ± 0.04^{a}	1.67 ± 0.02^{bcd}	375.00 ± 0.00^{e}	-	-
TS2	0.55 ± 0.00^{a}	1.62 ± 0.10^{abc}	1.72 ± 0.04^{de}	41.67 ± 14.43^{a}	-	-
MS	0.83 ± 0.01^{fg}	1.51 ± 0.05^{a}	1.37 ± 0.02^{a}	33.33 ± 14.43^{a}	-	-
CS	0.66 ± 0.01^{de}	1.59 ± 0.04^{ab}	1.53 ± 0.12^{ab}	41.67 ± 14.43^{a}	-	-
WF	0.62 ± 0.01^{bc}	1.53 ± 0.02^{a}	1.63 ± 0.07^{bcd}	125.00 ± 25.00^{bc}	9.39 ± 1.53^{b}	7.63 ± 0.23^{c}
RF	0.61 ± 0.02^{bc}	1.84 ± 0.01^{bcd}	1.89 ± 0.01^{ef}	-	3.37 ± 1.41^{a}	6.17 ± 1.26^{b}
GF	0.62 ± 0.01^{cd}	2.02 ± 0.06^{cde}	2.02 ± 0.06^{f}	183.33 ± 38.19^{c}	1.04 ± 0.02^{a}	1.03 ± 0.03^{a}
CF	0.58 ± 0.01^{ab}	1.72 ± 0.04^{de}	1.72 ± 0.04^{cde}	116.67 ± 28.87^{b}	1.03 ± 0.02^{a}	1.02 ± 0.02^{a}
PF	0.91 ± 0.02^{h}	1.38 ± 0.07^{de}	1.38 ± 0.07^{a}	166.67 ± 14.43^{bc}	6.82 ± 0.50^{b}	10.31 ± 0.21^{d}

Values are presented as mean±standard deviation, n = 3. Values with different superscripts within the same column are statistically significantly different ($p \leq 0.05$).

consideration in buying.

Bulk density is related to the fineness of particle size, moisture content, chemical composition, and the manufacturing process (Antarlina *et al.*, 2021; Hasmadi, 2021). It is used to determine flour and starch packaging size and distribution capacity (Amin *et al.*, 2021; Ogunka *et al.*, 2021). The higher the bulk density of flour or starch, the smaller the packaging volume required. In addition, flour with high bulk density indicates its suitability for use in mixed and processed foods, while flour with low bulk density is suitable for the manufacture of complementary foods for infants (Chandra *et al.*, 2015; Melese *et al.*, 2021). The bulk density of cocoyam corm flour was significantly higher than the other samples, except for MS and PF. Hasmadi (2021) found in various types of wheat flour that the higher the water content, the lower the bulk density because water molecules made flour granules agglomerated and the voids between particles were also getting bigger. Mohd Dom *et al.* (2021) reported that the larger the banana peel flour granules, the greater the volume of voids between granules therefore the bulk density decreased. This relationship between moisture content and bulk density was also found in this study, especially XF1 and XF2 which have low water content tend to have high bulk density, while WF, RF and GF which have high moisture content have a low bulk density tendency. Meanwhile, the use of starch in the food industry is more influenced by the levels of amylose, amylopectin, and phosphate than bulk density, which is not the focus of this study. These parameters affect starch characteristics such as crystallization and retrogradation, viscosity, pasting properties, gel strength, clarity, and stickiness (Xu *et al.*, 2017).

WAC is related to the ability of flour and starch to absorb and bind water in their molecular matrix. It plays an important role in determining the type of flour that has a good solubility level therefore it can be used as a thickener (Chandra *et al.*, 2015; Melese *et al.*, 2021), increase juiciness (Lindriati *et al.*, 2020), or increase the elasticity and plasticity of dough (Afifah *et al.*, 2021). Factors that affect high water holding capacity include particle size and content of components such as pectin and hemicellulose (Mohd Dom *et al.*, 2021) but also amylose-amylopectin content and starch phosphate group (Alqah *et al.*, 2022). Tuber-based flour samples (XF1, CF and PF) had higher WAC compared to starch and non-tuber starch samples. Protein content may have a significant effect on WAC because cassava starch has a much lower WAC than cassava flour, as also found by Punia *et al.* (2019) on low-protein versus high-protein wheat cultivars. Although cocoyam flour has a fairly high WAC, its use to substitute high protein ingredients can reduce the ability of the final product to bind water (Lindriati *et al.*, 2020). It is not clear what factors play a significant role in the low WAC of high protein wheat flour (WF), whether its moisture content, fat content, or others. Nwadili *et al.* (2019) also found that wheat flour had a lower WAC than cocoyam flour. Research on the effect of fat content on WAC needs to be done in the future.

Punia *et al.* (2019) also reported that protein content also affects OAC. OAC serves to determine which flour is suitable for products that require good fat absorption, for example, to increase savory taste or maintain fat-soluble flavors (Amin *et al.*, 2021), improve mouthfeel, to extend shelf life, especially in bakery products (Melese *et al.*, 2021). Cocoyam flour has a relatively low OAC compared to other flour and starch samples. This is supported by Lindriati *et al.* (2020) who found that the addition of cocoyam flour decreased OAC in meat analogues and John *et al*. (2021) who found that increasing levels of cocoyam flour reduced OAC in wheat, plantain, and cocoyam composite flour. In this case, cocoyam flour has the potential to be used for products that are not expected to absorb too much oil, such as deep-fried foods.

Swelling capacity is related to the type of commodity, manufacturing process, and particle size of flour (Chandra *et al*., 2015) and is related to WAC in increasing the viscosity of liquid and semi-liquid food products (Melese *et al.*, 2021). Previously, the content of amylose, amylopectin, and starch phosphate groups, as well as amylose and amylopectin chain length, influenced the swelling capacity and retrogradation process of flour and starch (Blennow, 2004). Roots and tubers tend to have a relatively higher swelling power than grains due to the larger size of starch granules (Ashogbon, 2022). Rice flour showed no visible volume expansion, which might be due to several factors such as having a relatively larger particle size compared to other flour and starch samples, making it more difficult for water to penetrate as well as being heavier and settling at the bottom of the centrifuge tube. Meanwhile, the two samples of tapioca starch (TS1 and TS2) have a massive difference in swelling capacity. It is suspected that TS1 is a product of pregelatinized starch which is easier to absorb and retain water without heating (Maniglia *et al*., 2021). Cocoyam flour has a high swelling capacity, in line with its high WAC. The same result was also found by Nwadili *et al*. (2019) who compared cocoyam flour with wheat flour. Therefore, cocoyam flour is likely to be suitable for products that require volume expansion when cooked with water, for example, noodles as suggested by Mohd Dom *et al.* (2021).

In terms of emulsion activity and emulsion stability, all starch samples could not emulsify, presumably due to their low protein content therefore they were not sufficient to form emulsions. Wheat flour has a high protein content and is in line with the highest emulsifying ability compared to other flour samples. Meanwhile, cocoyam flour has moderate emulsification ability. Increasing the content of cocoyam flour in a mixture of flour, plantain, and cocoyam composite flour decreased its emulsion ability (John *et al*., 2021). Based on the data, the emulsion stability of the flour samples decreased, except for potato flour which increased in volume due to starch gelatinization.

4. Conclusion

In conclusion, cocoyam flour has a low level of whiteness and relatively lower calories. The significant properties of cocoyam flour were relatively high bulk density, relatively high WAC, relatively low OAC, and high swelling capacity. Cocoyam flour also showed emulsion activity and stability.

Based on these characteristics, cocoyam flour is suitable for use in mixed and processed food products, especially those that require juicy, elastic, and volume expansion characteristics. However, additional protein is needed to maintain the structure. It is also recommended for food products that are lower in calories and are not expected to absorb too much oil. Cocoyam flour can also help to maintain viscosity and form emulsions. Food products that fully use cocoyam flour as raw material can be developed in future research.

Conflict of interest

The authors declare no conflict of interest.

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