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Physicochemical and Antioxidant Characteristic of Flakes with Arrowroot and Purple Yam Flour

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Abstract. The growing awareness of environmental impacts has encouraged the diversification of high–mileage commodities, including reducing wheat use in flakes. Purple yams and arrowroot show potential as a wheat substitute due to their antioxidant activity. In this study, wheat flour was partially substituted with arrowroot and purple yam flour at ratios of 30:65:5, 30:60:10, and 30:55:15. The products were evaluated for chemical and physical characteristics. Antioxidant activity ranged from 5.71-24.27%, with anthocyanin levels of 30.38-40.06%. Moisture content was 2.05-4.78%, ash 1.36-1.54% wb, protein 2.33-2.72% wb, fat 20.21-21.24% wb, and carbohydrate 71.05-73.65% wb. Physically, the flakes maintained crispiness in milk for 358.25-402.25 seconds, with hardness value of 2.20-3.35 F.maxN, crispiness of 1.59-2.28 F.breakN, and color values of L* 53.42-61.50, a* 4.51-9.14, and b* 11.73-18.17. Among the formulations, the 30:55:15 ratio produced the highest antioxidant activity and a higher anthocyanin content.

1 Introduction

The environmental awareness of both consumers and the food industry have been increasing. The environmental impact includes the carbon footprint derived from food processing and distribution, which highlights imported foods with high food miles [1]. One of the most highlighted commodities is wheat. USDA in 2025 reported that wheat export from the United States of America to various countries showed an uptrend, including to Indonesia, Libya, and Australia [2]. Wheat flour is the main ingredient of numerous foods, such as cereal flakes. It is necessary to find a substitute of wheat flour with local crops to limit the environmental impacts, lower the cost, and increase the physiological function of the product.

Purple yam (*Dioscorea alata*) thrives in both tropical and temperate climates, and has been extensively cultivated in South America, India, Indonesia, China, Japan, and the Philippines [3]. The purple color of the yam sources from anthocyanin, a compound with antioxidant properties. Antioxidants provide protection against free radicals and help prevent aging, cancer, degenerative diseases, stress, and act as an anti-inflammatory agent. Purple yam contains 16,64 mg of anthocyanin and 473,63 mg GAE of total phenolic content per 100 grams of sample (dry weight) [4].

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Arrowroot (*Maranta arundinacea* Lin.) is native to Mexico, Central and South America, but it grows well in other countries, including Indonesia [5]. Arrowroot starch has been used as a substitute for wheat flour in cookies because it is gluten-free, which is ideal for a dry and unleavened product. It gives the cookies a crispy and crunchy characteristic [6].

The abundant amounts of purple yams and arrowroot in several areas make a good substitution for imported wheat flour as a cereal flake main ingredient. This substitution could improves economic value of purple yams and arrowroot, which are considered unattractive and low economic commodities for locals. To our knowledge, studies on yam/arrowroot-based flakes already exist, but research using both ingredients on flakes has not yet been performed. The use of these two ingredients is expected to produce a product with antioxidant activity derived from the anthocyanin content from purple yams flour and a crispy texture from arrowroot flour. The study was conducted to examine the physicochemical properties of flakes made from arrowroot and purple yam flour and discuss the functional value potential from the antioxidant activity and anthocyanin of purple yam flour in the product.

2 Materials and Methods

2.1 Materials

Materials used to make the flakes were water, wheat flour, salt, sugar, margarine, and vanilla essence. Materials used for analysis were milk, methanol PA, DPPH (2,2-diphenyl-1 picryl-hydrazyl), a mixture of 95% ethanol and HCl 1.5N (85:15), and Aquadest.

Equipment used to make the flakes includes a basin, roller, oven, measuring cup, spoon, spatula, digital scale, noodle maker, baking paper, and baking pan. The equipment used for analysis were spectrophotometer UV-Vis, a Chromameter Konica Minolta CR-400, a Texture Analyzer, a blender, parafilm, Whatman filter paper No. 1, and glassware.

2.2 The Production of Flakes from Arrowroot and Purple Yam Flour

The product was made in two batches. The ingredients were weighed according to the formula in Table 1 to be mixed, flattened using a noodle maker, baked in the oven at 120 °C for 20 minutes, crushed into flakes, baked again at 110 °C for 10 minutes, then rested until the flakes reached room temperature (approximately 29°C) before being packed.

Table 1. Formulation of Flakes with Arrowroot and Purple Yam Flour.

Ingredients	F1	F2	F3
Wheat flour (g)	45	45	45
Arrowroot flour (g)	97.5	90	82.5
Purple yam flour (g)	7.5	15	22.5
Sugar (g)	40	40	40
Margarine (g)	60	60	60
Salt (g)	1	1	1
Vanilli (g)	3	3	3
Water (g)	100	100	100

2.3 Chemical Characteristics

2.3.1 Proximate Analysis

The proximate of the product was analyzed, including moisture content, ash content, protein content using the Kjeldahl method, fat content using the Soxhlet method, and carbohydrate content calculated from the content differences [7].

2.3.2 Antioxidant Activity Analysis

The antioxidant activity analysis was done using DPPH analysis [8]. A total of 0.2 gram sample was added with 5 ml of methanol PA, then vortexed. A total of 0.2 ml of the extract was taken. A total of 2.8 ml DPPH reagent 0.1 mM was then added to the extract, and the solution was incubated in a dark room for 1 hour at room temperature. Absorption was then analyzed with a spectrophotometer with a 515 nm wavelength and blanks of 0.2 ml methanol and 2.8 ml DPPH reagent, 0.1 mM. The percentage of DPPH was calculated using the following formula:

$$\% DPPH = (Acontrol - Asample)/Acontrol \times 100\%) \ x \ 100\% \quad (1)$$

2.3.3 Anthocyanin Analysis

The anthocyanin analysis was done based on [9]. A total of 100 gram of sample was extracted with 100 mL of ethanol 95% and HCl 1.5 N mixture (85:15) in a high-speed blender for 2 minutes. The extract was then closed with parafilm and stored overnight at 4 °C to be later filtered using Whatman filter paper No. 1 and added with 500 ml of solvent. A total of 2 mL of the extract was then added to the solvent until 100 mL (dilution factor 25000). The extract was then stored in a dark room for 2 hours at room temperature. The absorption was then analyzed using a spectrophotometer at a 535 nm wavelength and blanks of water. The total of anthocyanins was calculated using the following formula:

$$Total\ anthocyanin\ (mg/100g) = (absorption\ x\ dilution\ factor)/98{,}2 \quad (2)$$

2.4 Physical Characteristics

2.4.1 Crispy Resistance in Milk

A total of 1.5 grams of flakes was placed in a bowl, then added with 70 ml of milk at 25 °C. Resistance was determined by measuring the time the flakes remained floating.

2.4.2 Texture Analysis

The hardness and crispiness were analyzed using a Universal Testing Machine. The pre-load force used was 0.01 N with the pre-load speed of 300 mm/min and a test speed of 10 mm/min.

2.4.3 Color

The color of the product was analyzed based on the L*, a*, and b* values using Chromameter Konica Minolta CR-400. The L* value shows the brightness of the product from black (value of 0) to white (value of 100), the a* value indicates redness (a+) and greenness (a-), b* value indicates yellowness (b+) and blueness (b-) from the product.

2.5 Statistical Analysis

The statistical analysis was conducted using R Studio using the One-Way Anova with Duncan Multiple Range Test (DMRT) post-hoc was used for fat and carbohydrate content, crispiness resistance in milk, hardness, cripsiness and L value. The Kruskal-Wallis method was used in the other analysis. The significance value was set at 0.05.

3 Results and Discussion

3.1 Chemical Characteristics

The chemical characteristics of the flakes made from arrowroot and purple yam flour, based on the proximate analysis, antioxidant activity, and total anthocyanin are shown in Table 2. Based on the data, increasing the proportion of purple yams substitution raises the antioxidant activity, anthocyanin, moisture, and ash content while reducing the protein and carbohydrate content.

Table 2. Chemical characteristics of Flakes made from Arrowroot and Purple Yam Flour.

Parameter	F1	F2	F3
Moisture content (%)	2.05±0.35^{a}	2.45±1,34^{a}	4.78±1.20^{b}
Ash content (% wb)	1.36±0.05^{a}	1.54±0.01^{b}	1.47±0.07^{ab}
Fat content (% wb)	20.21±0.51^{a}	21.24±0.42^{b}	20.41±0.33^{a}
Protein content (% wb)	2.72±0.18^{b}	2.33±0.02^{a}	2.35±0.13^{a}
Carbohydrate content (% wb)	73.65±0.73^{b}	72.51±0.90^{b}	71.05±0.72^{a}
Anthocyanin (mg/100 g)	30.38±0.30^{a}	35.64±0.48^{ab}	40.06±1.97^{b}
DPPH antioxidant activity (%)	5.71±0.20^{a}	17.71±0.12^{ab}	24.27±0.20^{b}

Note:
- The ratio of wheat flour: arrowroot flour: purple yam flour of F1, F2, and F3 were consecutively 30:65:5; 30:60:10; and 30:55:15
- Numbers in the same row and followed by the same letter show no significant difference based on the Kruskall-Wallis or DMRT at 5% of significance

The moisture content of the product ranged from 2.05±0.35 to 4.78±1.20%. Purple yam flour has a higher fiber (1.83 and 1.00%) and amylose (24.58-37.93 and 24.95%) content than arrowroot flour, leading to higher water holding capacity (WHC), thus maintaining the moisture in the product better [4,10,11]. Flakes with a higher purple yam flour composition showed higher moisture content. The baking process was able to lower the moisture content of the product. Products with high moisture content are more susceptible to microbial growth and shorter shelf life. The moisture content is lower than flakes made from mocaf-black rice-tapioca with soy and jack bean flour addition and flakes made from cassava flour, which ranges from 10.385-11.035% [12,13].

The ash content of the product ranged from 1.36±0.05 to 1.54±0.01% and tended to increase with the increasing amount of purple yam flour. The purple yam flour has a higher ash content than arrowroot flour (2.35 and 1.12%); thus, the increasing amount of purple yam flour would increase the ash content in the product [10,11]. The ash content of a food product indicated the presence of inorganic elements in the product, including minerals and debris. The ash content of the product is lower than that of flakes made from mocaf-black rice-tapioca with soy and jack bean flour addition and flakes made from cassava flakes, which range from 1.515-2.650% and 2.3% [12,13].

The fat content of the product ranged from 20.21±0.51 to 21.24±0.62%. Because arrowroot and purple yam flours have low fat content (0.26 and 0.28%), flour substitution had little effect on the product's fat level [10,11]. The fat content of the product might come from the margarine. The high fat content of a food product makes it more prone to rancidity, which could be lowered by controlling the oxygen with packaging or an oxygen absorber. The fat content was higher than flakes made from mocaf-black rice-tapioca with soy and jack bean flour addition and cassava flakes, which range from 3.425-4.945% and 0.3% [12,13].

The protein content ranged from 2.33±0.02 to 2.72±0.14%, increasing with higher levels of arrowroot flour. This trend may be influenced by moisture content, which affects proximate proportion, including protein. However, the protein content in this product is lower than flakes made from mocaf-black rice-tapioca with soy and jack bean flour addition and flakes made from cassava flour, which range from 5.755-10.110% and 6.6%. Protein is one of the most important parameters that could affect the consumers' perception of the product. Further research with addition of other ingredients to increase the protein content needs to be conducted [12,13].

The carbohydrate content of the product ranged from 71.05±0.72 to 73.65±0.73%. The increasing amount of purple yam flour used increases the carbohydrate content of the product. This characteristic might occur from the higher moisture content that affects the proximate proportion, including the carbohydrate content. Carbohydrates, which contain amylose and amylopectin starch, may affect the texture of the product. Higher amylose content leads to a firmer and harder texture of the product. The carbohydrate content in this product is lower than flakes made from mocaf-black rice-tapioca with soy and jack bean flour addition and flakes made from cassava flour, which range from 85.135-87.710% and 89.0%. [12,13].

As presented in Table 2, the total anthocyanin and antioxidant activity are increasing as the proportion of purple yam flour substitute increases. Purple yams have a total anthocyanin level of 16,64 mg/ 100 g sample, indicating that the product has a higher antioxidant activity[4]. Diosgenine, dioscine, and dioscorine, which also act as antioxidants, were also found in yams. These compounds can be found in several plants and have anti-microbial, anti-diabetic, anti-cancer, anti-inflammatory, and anti-obesity properties [14].

3.2 Physical Characteristics

Texture is one of the most important sensory features in flakes that affects consumers' perception. The texture of the products was analyzed by their hardness (F.maxN), crispiness (F.breakN), and crispiness resistance in milk (seconds) as shown in Table 3.

Based on the data below, the substitution of arrowroot flour for purple yam flour did not affect the crispiness of flakes, but it increased the hardness of the flakes (2.20±0.09 to 3.35±0.30 F.maxN with the highest result in the product with the highest purple yam substitution). The hardness might come from the higher amylose content of purple yams than arrowroot flour [4,10].

The crispiness resistance in milk was around 358.25±7.54 to 402.25±10.24 seconds, or approximately 5-6 minutes, with lower resistance in the product with high purple yam flour substitute. Higher amylose content in purple yams absorbs more water and milk, resulting in the inability to retain its crispiness.

Table 3. Physical characteristics of Flakes made from Arrowroot and Purple Yam Flour.

Ingredients	F1	F2	F3
Crispy resistance in milk (second)	402.25±10.24^{c}	375.75±4.79^{b}	358.25±7.54^{a}
Hardness (F.maxN)	2.20±0.09^{a}	2.77±0.04^{b}	3.35±0.30^{c}
Crispiness (F.breakN)	1.59±0.68^{a}	2.28±0.60^{a}	1.60±1.01^{a}
L	61.50±0.61^{c}	55.90±1.02^{b}	53.42±2.15^{a}
a*	4.51±0.42^{a}	7.85±0.17^{ab}	9.14±0.11^{b}
b*	18.17±0.22^{b}	12.63±0.61^{a}	11.73±1.15^{a}

Note:
- The ratio of wheat flour: arrowroot flour: purple yam flour of F1, F2, and F3 were consecutively 30:65:5; 30:60:10; and 30:55:15
- Numbers in the same row and followed by the same letter show no significant difference based on the Kruskall-Wallis or DMRT at 5% of significance

The purple pigment from anthocyanin compounds is resistant to a wide range of temperatures and pH. Anthocyanins gave a unique redish, purplish, and blueish color to several plants, as presented in Table 3 [4]. The L* (lightness) and b* (yellowness) value decreased while the a* (redness) value increased with higher levels of purple yam flour. Similar results has been reported in stick crackers [15].

4 Conclusion

The ratio of arrowroot and purple yam flour affects the physical and chemical characteristics of flakes. Increasing the proportion of purple yam flour in flakes enhanced antioxidant activity, anthocyanin, moisture and ash level, lower protein and carbohydrate content, lower crispiness resistance in milk, harder texture, and purplish color. The combination of arrowroot and purple yams is a potential alternative flakes with lower wheat flour content. The limitation of this study is focusing on the antioxidant properties of the product using ingredients with high carbohydrate content. Research with the addition of other ingredients to increase the protein content needs to be conducted. Further research on safety, shelf life, application of preservatives, and/or packaging could also be conducted to ensure product safety, quality, and stability during storage.

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References

1. F. C. Coelho, E. M. Coelho, and M. Egerer, Local food: benefits and failings due to modern agriculture. Sci. Agric. **75**, 84 (2018). https://doi.org/10.1590/1678-992X-2015-0439
2. Grain: World Markets and Trade (2025). https://public.govdelivery.com/accounts/USDAFAS/subscriber/new (accessed January 7, 2026).

3. G. Suvathika, S. P. Manoharan, S. Baskar, A. Rajiv, H. Swaminathan, and S. A. Yadav, Evaluation and identification of nutritional factors, cytotoxic condition, and protodioscin in Dioscorea alata tuber. South African Journal of Botany **178**, 131 (2025). https://doi.org/10.1016/J.SAJB.2025.01.010
4. A. Shrivastava, R. K. Gupta, and P. P. Srivastav, Exploring novel frontiers of advancements in purple yam (*Dioscorea alata L.*) starch extraction, modification, characterization, applications in food and other industries. Measurement: Food **15**, 100196 (2024). https://doi.org/10.1016/j.meafoo.2024.100196
5. J. Rojas-Sandoval, Maranta arundinacea (arrowroot). CABI Compendium (2018). https://doi.org/10.1079/CABICOMPENDIUM.32455
6. I. Kusumaningrum, R. N. Afiah, and S. D. Nur'aini, Evaluation of consumer preference and nutritive values of gluten-free cookies from arrowroot (*Maranta arundinaceae L.*) starch and rice flour. Gizi Indonesia **48**, 149 (2025). https://doi.org/10.36457/gizindo.v48i2.1062
7. G. W. Latimer, editor , Official Methods of Analysis of AOAC INTERNATIONAL (Oxford University Press, New York, 2023). https://doi.org/10.1093/9780197610145.001.0001
8. W. Brand-Williams, M. E. Cuvelier, and C. Berset, Use of a free radical method to evaluate antioxidant activity. LWT - Food Science and Technology **28**, 25 (1995). https://doi.org/10.1016/S0023-6438(95)80008-5
9. D. H. Lees and F. J. Francis, Standardization of pigment analyses in cranberries 1. HortScience **7**, 83 (1972). https://doi.org/10.21273/HORTSCI.7.1.83
10. M. K. S. Malki, J. A. A. C. Wijesinghe, R. H. M. K. Ratnayake, and G. C. Thilakarathna, Characterization of arrowroot (*Maranta arundinacea*) starch as a potential starch source for the food industry. Heliyon **9**, e20033 (2023). https://doi.org/10.1016/j.heliyon.2023.e20033
11. A. Yalindua, N. Manampiring, F. Waworuntu, and F. Y. Yalindua, Physico-chemical exploration of yam flour (*Dioscorea alata L.*) as a raw material for processed cookies. J. Phys. Conf. Ser. **1968**, 012004 (2021). https://doi.org/10.1088/1742-6596/1968/1/012004
12. E. Najjingo, S. Byakika, and I. M. Mukisa, Physical properties, nutritional profile, and consumer acceptability of gluten-free breakfast flakes from cassava flour. Applied Food Research **4**, 100541 (2024). https://doi.org/10.22437/ifstj.v6i2.21133
13. F. C. Agustia, S. Rosyidah, Y. P. Subardjo, G. R. Ramadhan, and D. Betaditya, Formulation of Flakes made from mocaf-black rice-tapioca high in protein and dietary fiber by soy and jack bean flour addition. IOP Conf. Ser. Earth Environ. Sci. **255**, 012019 (2019). https://doi.org/10.1088/1755-1315/255/1/012019
14. B. Kaur, S. Khatun, and A. Suttee, Current highlights on biochemical and pharmacological profile of Dioscorea alata : A review. Plant Arch. **21**, 552 (2021). https://doi.org/10.51470/PLANTARCHIVES.2021.v21.S1.085
15. Y. G. Armando, Ulyarti, M. Rulaini, Mursyid, F. Tafzi, Surhaini, and Nazarudin, The application of purple yam flour for stick crackers. Indonesian Food Science and Technology Journal **6**, 40 (2023). https://doi.org/10.22437/ifstj.v6i2.21133