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Effect of steaming on the physicochemical characteristics, color, and antioxidant activity of purple sweet potato (*Ipomoea batatas L.)* flour

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ABSTRACT

Purple sweet potato (Ipomoea batatas L.) is a natural source of anthocyanins with potential application as a functional food ingredient. This study aimed to evaluate the effect of steaming on the physicochemical characteristics, color properties, and antioxidant activity of purple sweet potato flour. Two treatments were applied: without steaming (P2) and steaming for approximately 10 minutes prior to drying (P1). Steaming was performed after sorting, washing, and slicing of the raw material and before dehydration. Samples were dried using a food dehydrator at 50°C for 6–8 h, ground, and sieved through an 80-mesh. Each treatment was analyzed in duplicate. The analyzed parameters included moisture content, ash content, pH, antioxidant activity (IC_{50}), water absorption capacity (WAC), oil absorption capacity (OAC), and color values (L, a*, b*). Data were analyzed using ANOVA at a 5% significance level. Steaming significantly increased moisture content (from 6.85% to 10.15%), ash content (from 2.85% to 3.45%), and pH (from 5.96 to 6.15), and significantly decreased antioxidant activity, with IC50 increasing from 63.57 ppm (strong antioxidant) to 144.70 ppm (moderate antioxidant) ($p<0.05$). No significant effects were observed on WAC and OAC. Steaming also reduced the L*, a*, and b* values, indicating lower brightness and color intensity. These findings indicate that purple sweet potato can be processed into flour while maintaining favorable physicochemical characteristics and bioactive compounds, highlighting its potential as an ingredient for the development of various functional food products.*

Keywords: antioxidant activity; physicochemical properties; purple sweet potato; steaming; sweet potato flour

INTRODUCTION

Purple sweet potato (*Ipomoea batatas* L.) is an important tuber crop that is widely consumed in various regions of the world (Belkacemi, 2022). Belonging to the family *Convolvulaceae*, sweet potato is extensively cultivated in tropical, subtropical, and temperate regions and contributes to food quality and nutritional security. Among the various sweet potato varieties, purple sweet potato has received considerable attention because of its characteristic purple pigmentation, which is attributed to the presence of anthocyanins, particularly peonidin, cyanidin, and pelargonidin derivatives. In addition to anthocyanins, purple sweet potato contains starch, dietary fiber, proteins, vitamins, minerals, flavonoids, and phenolic acids, all of which contribute to its functional value (Jiang et al., 2022). The abundance of bioactive compounds in purple sweet potato highlights its potential as a functional food ingredient with strong antioxidant properties.

Despite its considerable potential, purple sweet potato is highly perishable after harvest, with a relatively short shelf life that limits storage and distribution in fresh form. One strategy to extend its shelf life is conversion into flour, which can serve both as a partial substitute for wheat flour and as a source of natural pigments and bioactive compounds.The quality characteristics of purple sweet potato flour are affected by several factors, including cultivar, processing techniques, pretreatment methods, and drying conditions. Therefore, processing approaches that can minimize the degradation of bioactive compounds are essential to preserve the functional properties of the flour (Monteiro et al., 2025).

Pretreatment prior to drying, particularly blanching using hot water or steam, is commonly applied to inactivate polyphenol oxidase and peroxidase, reduce microbial load, and maintain product quality during drying. However, the effect of such pretreatments on flour quality varies considerably depending on the blanching medium, duration, and raw material. Rahmawati et al., (2017) reported that blanching for 3 min combined with soaking for 120 min produced the most favorable characteristics in pumpkin flour, with a protein content of 8.21%, moisture content of 9.17%, bulk density of 0.487 g/cm³, viscosity of 13,896 cP, and yield of 11.66%.

Aminah & Hersoelistyorini (2017) found that boiling-blanched cereal and legume sprout flours had lower total phenolic content than steamed or roasted samples, likely due to flavonoid degradation during prolonged thermal exposure. Similary, Belkacemi (2022) reported that blanching reduced polyphenol and tannin contents in sweet potato flour, while the combination of non-peeling and blanching improved water absorption capacity, swelling power, water solubility, and emulsifying capacity. Furthermore, Canteri (2018) stated that blanching can enhance protein and soluble fiber availability through inactivation of protease, pectinase, polyphenol oxidase, and peroxidase, while also reducing total phenolic content due to the heat sensitivity of these compounds. These findings collectively indicate that thermal pretreatment before drying can substantially alter the physicochemical, functional, and bioactive properties of root and tuber flours, with the direction and magnitude of the effect depending on the heating medium (*water or steam*) and processing conditions used. Moreover, flour production technique significantly affects moisture content, bulk density, color, and starch microstructure, underscoring that processing choices, not only pretreatment, shape the final product characteristics (Syamsir & Honestin, 2019).

Most previous studies on thermal pretreatment of sweet potato flour have focused on water blanching, often combined with chemical soaking solutions, whereas the specific effect of steaming, a pretreatment that limits direct contact between the raw material and water, combined with food dehydrator drying has rarely been investigated for purple sweet potato. This combination is of practical interest because food dehydrators are widely accessible at the small and household production scale in Indonesia, and steaming may better preserve water-soluble bioactive compounds compared with water blanching. Hence, this study was conducted to evaluate the effect of steaming on the physicochemical characteristics, color, and antioxidant activity of purple sweet potato flour dried using a food dehydrator, providing baseline data to support the development of purple sweet potato flour as a functional food ingredient.

METHODOLOGY

Purple sweet potatoes were obtained from Wonogiri City Market, Central Java, Indonesia. The raw materials were sorted based on uniform size, full maturity, and the absence of physical defects or signs of decay, then washed and sliced into pieces of uniform size (± 1 cm x 1 cm).

Two treatments were applied in this study: flour without steaming (P2) and flour subjected to steaming for approximately 10 minutes (P1). Steaming was performed using a household steamer with the slices placed in a perforated steaming basket above boiling water (approximately 100°C at the steam plate), with the 10 minute duration measured from the time steam fully enveloped the sample. Steaming was carried out immediately after slicing and prior to drying. The samples were then dried using a food dehydrator at 50°C for approximately 6-8 hour. The dried samples were subsequently ground using a blender and sieved through an 80-mesh sieve to obtain uniform purple sweet potato flour.

Each treatment was prepared in duplicate (n = 2), and all analyses were performed in duplicate measurements per replicate. The resulting flour was analyzed for its physicochemical and functional characteristics, including moisture content, ash content, pH, antioxidant activity, water absorption capacity (WAC), oil absorption capacity (OAC), and color characteristics using a chromameter (Belkacemi, 2022; Marliana et al., 2026; Maulidya et al., 2025). The data were analyzed using SPSS software. Analysis of variance (ANOVA) was performed to determine the effect of treatment at a significance level of 5%.

RESULTS AND DISCUSSION

The physicochemical characteristics, functional properties, and antioxidant activity of purple sweet potato flour obtained from the non-steamed treatment and steaming treatment for approximately 10 minutes are presented in Tables 1 and 2. Based on the results of ANOVA at a 5% significance level, steaming significantly increased the moisture content, pH, and IC50 (i.e., decreased antioxidant activity) of purple sweet potato flour. In contrast, ash content, WAC, and OAC did not differ significantly between treatments. This pattern suggests that the heat and moisture exposure during steaming more strongly affected heat-labile bioactive compounds and water-related chemical equilibria (moisture, pH) than the protein- and starch-related functional properties governing WAC and OAC, which are primarily determined by macromolecular structure rather than by short steaming exposure (Wang et al., 2017).

Table 1.
Physicochemical characteristics of purple sweet potato flour

Parameter	P1	P2
Ash content (%)	3.45 0.00	2.85 ± 0.24
Moisture content (%)	10.15 0.12	6.85 ± 0.03
pH	6.15 0.14	5.96 ± 0.14
Antioxidant Activity/IC_{50} (ppm)	144.70 0.07	63.57 ± 0.07
Water Absorption Capacity (WAC)	2.63 0.02	2.71 ± 0.10
Oil Absorption Capacity (OAC)	1.09 0.00	1.13 ± 0.05

*P1 = Purple sweet potato flour subjected to steaming before drying; P2 = Purple sweet potato flour without steaming before drying

Table 2.
Color characteristics of purple sweet potato flour

Sample	L*	a*	b*
P1	35.17 ± 0.10	14.28 ± 0.42	0.67 ± 0.10
P2	51.50 ± 0.61	17.32 ± 0.49	5.57 ± 0.03

Ash Content

The ash content of purple sweet potato flour was 2.85% in the non-steamed treatment (P2) and increased to 3.45% in the steamed treatment (P1). The ash content represents the total mineral content of a food material, including calcium, phosphorus, magnesium, potassium, iron, zinc, and copper (Toan et al., 2018). The values obtained in the present study fall within the range of ash content reported for sweet potato flour by Putri (2019), which ranged from 2.58% to 5.31%. The absence of a significant effect of steaming on ash content is consistent with the relatively high thermal stability of minerals, since minerals are not destroyed by heat and have low volatility; reported mineral losses during thermal processing are generally limited and mainly attributable to leaching into the processing water rather than heat-induced destruction (Yadav et al., 2023). As steaming involves minimal direct contact between the sample and water, mineral loss through leaching was likely limited, which may explain the absence of a significant treatment effect.

Moisture Content

The moisture content of purple sweet potato flour was 10.15% in the steamed treatment (P1) and 6.85% in the non-steamed treatment (P2). Analysis of variance indicated that steaming significantly affected the moisture content of purple sweet potato flour. The higher moisture content in the steamed treatment may be attributed to steam penetrating the sweet potato tissue and inducing changes in starch gelatinization and cell microstructure during heating, which can alter water distribution and binding within the tissue, allowing part of the absorbed moisture to remain bound despite subsequent drying under identical conditions (Xie et al., 2023).

According to Toan et al. (2018), the moisture content of sweet potato flour generally ranges from 2.50% to 13.2%; the values obtained in the present study fall within this range. Since both treatments in this study used the same purple sweet potato cultivar, raw material maturity, slice dimensions, and drying conditions, the only variable distinguishing the two treatments was the presence or absence of steaming. The higher moisture content of the steamed sample is therefore most plausibly explained by the steam-induced structural changes described above, rather than by raw material variation (Maulidya et al., 2025). This treatment-specific effect on moisture content is important because excessive residual moisture can compromise the storage stability of the flour by promoting chemical degradation and microbial growth (Fadhli et al., 2023). The result indicates that steaming pretreatment, despite being applied prior to a drying step identical for both treatments, leaves a measurable residual effect on final product moisture, an effect that should be considered when steaming is adopted at production scale.

pH

The steamed treatment (P1) resulted in a higher pH value than the non-steamed treatment (P2), and ANOVA revealed that the difference was statistically significant ($p < 0.05$). The increase in pH following steaming was likely associated with heat-induced degradation or volatilization of organic acid compounds during heating. Unlike enzymes, organic acids are not inactivated by heat; rather, thermal exposure can promote their decarboxylation or volatilization, or shift the balance between free and bound acidic compounds, thereby reducing the concentration of titratable acids and increasing the measured pH. The findings of this study are consistent with those reported by Ann et al. (2021) which found that steamed samples exhibited the highest pH values compared to other treatments. However, these findings differ from those reported by Fitriani et al. (2023), who applied water blanching at 70°C and 90°C combined with soaking in Na-metabisulfite or citric acid solution and found that this treatment decreased the pH of purple sweet potato flour. The present study applied steaming without soaking, whereas previous studies used water blanching combined with an acidic soaking solution. The discrepancy is more likely attributable to the additional acid treatment and direct water contact in the previous studies' protocols than to the heating method alone.

Antioxidant Activity

The antioxidant activity of purple sweet potato flour was evaluated using the DPPH assay, yielding IC_{50} values of 144.70 ppm for P1 (steamed treatment) and 63.57 ppm for P2 (non-steamed treatment). The DPPH assay measures the ability of antioxidant compounds to inhibit 50% of DPPH free radicals, with the results expressed as IC_{50} values. Lower IC_{50} values indicate stronger antioxidant activity (Marliana et al., 2026).

ANOVA revealed that steaming had a significant effect on the antioxidant activity of purple sweet potato flour. Based on the IC50 classification of Molyneux (2004), in which IC50 < 50 ppm is categorized as very strong, 50–100 ppm as strong, 100–150 ppm as moderate, and 150–200 ppm as weak, the non-steamed sample (63.57 ppm) was categorized as a strong antioxidant, whereas the steamed sample (144.70 ppm) was classified as a moderate antioxidant. These findings indicate that steaming reduced the antioxidant activity of purple sweet potato flour. The observed decline in antioxidant activity may be attributed to the degradation of bioactive compounds, particularly anthocyanins and phenolic compounds, which are susceptible to thermal treatment. Exposure to heat can alter the chemical structure of antioxidant compounds, resulting in a reduced capacity to scavenge free radicals. Thermal treatments such as steaming have similarly been reported to reduce tannin content because tannins are thermolabile and water-soluble compounds (Noi et al., 2021).

The results of this study indicate that the degradation of antioxidant compounds during steaming was more pronounced than the protective effect resulting from the inactivation of oxidative enzymes, leading to a reduction in the antioxidant activity of purple sweet potato flour after steaming. These findings differ from those reported by Ann et al. (2021), who observed that steaming enhanced the retention of antioxidant components through inhibition of polyphenol oxidase activity; this discrepancy may be attributed to differences in steaming duration, sample size, and raw material characteristics between the two studies.

WAC and OAC

The water absorption capacity (WAC) of purple sweet potato flour was 2.63 g/g in the non-steamed treatment and increased slightly to 2.71 g/g after steaming, while the oil absorption capacity (OAC) was 1.09 g/g in the non-steamed treatment and 1.13 g/g in the steamed treatment. The steaming treatment tended to increase both WAC and OAC values; however, ANOVA revealed that these differences were not statistically significant.

WAC reflects the ability of a material to absorb and retain water and is influenced by factors such as dietary fiber content and starch characteristics. Higher WAC values indicate a greater ability of starch granules to bind and retain water in a dispersed system (Wang et al., 2017). The slight, non- significant increase in WAC after steaming observed in this study is consistent with the limited structural disruption expected from a short (10-minute) steaming exposure, which may not be sufficient to substantially alter starch granule integrity or fiber matrix porosity (Belkacemi, 2022).

OAC describes the ability of a material to absorb and retain oil, which plays an important role in the development of texture, flavor, and stability of food products. This capacity is influenced by interactions between oil and proteins through hydrophobic interactions, electrostatic forces, and hydrogen bonding (Lakhawat, 2019; Wang et al., 2017). In this study, the steaming treatment did not significantly affect the OAC value, although a slight increase was observed compared to the non-steamed treatment. These findings suggest that steaming for approximately 10 minutes did not induce sufficient structural modifications in the material to significantly enhance its oil-binding capacity. Increased OAC following blanching is generally associated with the formation of a porous microstructure that promotes greater interactions between proteins and oil. However, this effect appears not to have developed optimally under the processing conditions applied in the present study (Ohizua et al., 2017).

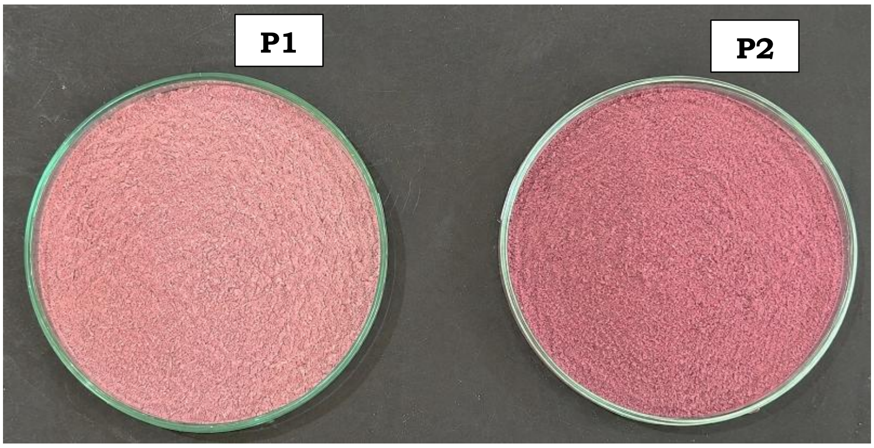

Figure 1. The comparison of flour particle size (P1= Purple sweet potato flour subjected to steaming before drying; P2 = Purple sweet potato flour without steaming before drying)

Color

Color is an important quality parameter that can be used as an indicator of the intensity of thermal treatment during processing (Machado et al., 2024). The lightness (L*) value of the steamed treatment (P1) was 35.17, which was lower than that of the non-steamed treatment (P2) at 51.50, indicating that the flour produced from the steaming treatment exhibited a darker color. The decrease in the L* value indicates a reduction in lightness as a result of heat treatment. The decrease in L* observed after steaming was likely associated with the degradation of natural pigments, particularly anthocyanins, which are sensitive to high temperatures, resulting in a darker color (An et al., 2022).

The positive a* and b* values observed in both treatments indicate that the resulting purple sweet potato flour still contained red and yellow color components (Syamsir & Honestin, 2019). However, the steaming treatment caused the a* value to decrease from 17.32 to 14.28 and the b* value to decrease from 5.57 to 0.67. The reduction in these two parameters indicates a decrease in the intensity of the red and yellow color components after steaming. This condition is likely attributed to the degradation of heat-sensitive pigment compounds, resulting in flour with lower color brightness and saturation compared to the non-steamed treatment. These findings are consistent with the observed decrease in antioxidant activity following steaming, suggesting alterations in pigmented bioactive compounds, such as anthocyanins, during the heating process.

CONCLUSION

The steaming pretreatment prior to drying significantly increased the moisture content, ash content, and pH of purple sweet potato flour, and significantly reduced its antioxidant activity (IC50 increased from 63.57 ppm to 144.70 ppm), while WAC and OAC were not significantly affected. Steaming also reduced the L*, a*, and b* color values, indicating a darker flour with lower red and yellow color intensity, most likely due to thermal degradation of anthocyanins and other heat-sensitive pigments. Therefore, the selection of an appropriate processing method is an important factor in maintaining the quality of purple sweet potato flour. The results of this study indicate that purple sweet potato has considerable potential to be developed as a functional flour ingredient that can be utilized in various value-added food products.

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