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Physical Properties and Panelists' Preference for Purple Sweet Potato Flour Flakes with Okara Flour Substitution

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ABSTRACT

Purple sweet potato flour is a promising flake component due to its elevated carbohydrate and antioxidant levels. Nonetheless, its very low protein content requires the incorporation of supplementary ingredients, such as okara flour, which is abundant in protein and fiber, to enhance the nutritional profile of the final product. This study investigates the impact of replacing purple sweet potato flour with okara flour on flakes' physical properties (texture and rehydration capacity) and sensory acceptance (organoleptic qualities). A one-factor Completely Randomized Design (CRD) was employed with five replacement levels: P0 (100%:0%), P1 (90%:10%), P2 (80%:20%), P3 (70%:30%), and P4 (60%:40%). The results showed that the substitution markedly influenced texture ($p = 0.016$) and rehydration capacity ($p = 0.000$), with increased okara levels resulting in firmer flakes and enhanced rehydration. Substitution markedly affected panelists' preferences for taste ($p = 0.000$), texture ($p = 0.000$), and color ($p = 0.025$), but not scent ($p = 0.725$). Elevating okara levels often diminished preference for flavor and texture, although color was favored at elevated okara concentrations. The optimal formulation was achieved with a 20% replacement of okara.

Keywords: flakes, purple sweet potato flour, okara (soy pulp) flour

1. INTRODUCTION

Flakes are ready-to-eat cereal products typically manufactured from high-starch carbohydrate sources (Purnamasari & Putri, 2014). Standard bases include corn (corn flakes), wheat (wheat flakes), and rice (rice flakes). Advances in food technology have encouraged the use of alternative raw materials such as tubers, legumes, and even nutrient-dense by-products like okara, coconut meal, or fruit peels (Hidayat et al., 2020). One example is the use of purple sweet potato flour for flakes.

Purple sweet potato (Ipomoea batatas L.) is widely cultivated in Indonesia and has strong potential as a functional food source. It is high in carbohydrates, relatively low in sugar, and contains fiber, protein, vitamin C, and minerals such as calcium, phosphorus, and iron. Cahyaningsih (2018) It is also stated that purple sweet potato is rich in anthocyanins, which act as natural antioxidants and provide an attractive purple hue. Purple sweet potato helps diversify the

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food supply and promotes a local carbohydrate alternative to rice and wheat. Its anthocyanins can improve the visual appeal of flakes. According to Paramita & Mulwinda in Hapsari et al. (2022), tubers are not protein-dense (Paramita & Mulwinda in Hapsari et al., 2022), so adding higher-protein ingredients such as soybean or okara flour can improve the nutritional quality of purple sweet potato-based flakes.

Okara is the residue that remains after extracting soy milk during tofu processing. Because many small-scale processors use simple, traditional methods, not all protein is fully extracted, leaving okara relatively protein-rich. Per 100 g of fresh wet okara, the composition is approximately carbohydrate 11.07%, protein 4.71%, fat 1.94%, and ash 0.08% (Sutriswati dalam Fransiska & Deglas, 2017). Incorporating okara in food improves nutrition and reduces underutilized tofu-industry waste. For example, a 60% wheat flour and 40% okara flour blend produced the best snack bar characteristics (Subamia et al., 2020). However, higher okara levels can increase beany notes and reduce liking (Setiadi dan Ambarwati, 2014).

Previous studies on flakes show promise. Mei Rani et al., (2021) reported that a 70% purple sweet potato flour and 30% soybean flour blend yielded the best flakes based on proximate composition, anthocyanin content, antioxidant activity, and water absorption, and was well-liked overall. (Hapsari et al., 2022) similarly found the 70:30 purple yam to soybean flour ratio most preferred in color, aroma, and texture.

Thus, responding to growing consumer interest in nutrition, this study develops purple sweet potato-based flakes with okara flour substitution, evaluates physical characteristics (texture and rehydration capacity), assesses panelist acceptance, and identifies the best-accepted treatment.

2. RESEARCH METHODS

Study Site and Period

The study was performed in the Agroindustry Laboratory, Universitas 17 Agustus 1945 Surabaya, between May and July 2025. The stages encompassed raw material preparation, preliminary analysis, product formulation, primary experimentation, and evaluation of physical attributes and sensory acceptance.

Materials and Equipment

Ingredients: purple sweet potato flour (Healthy Choice), fresh okara from a local tofu manufacturer, tapioca flour (Rose Brand), sugar (Gulaku), salt (Cap Kapal), water, margarine (Blue Band), and analytical reagents for chemical analysis.

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Equipment: plastic containers, scale, blender, spoons, knives, cutting board, trays, gas burner, pot, baking sheets, oven, measuring cylinders, aluminum foil, noodle maker, baking molds, and laboratory apparatus for chemical analysis.

Experimental Design and Methodology

A one-factor Completely Randomized Design (CRD) was employed, with purple sweet potato flour partially substituted with okara flour at five levels, with three replicates: P0 (100%:0%), P1 (90%:10%), P2 (80%:20%), P3 (70%:30%), P4 (60%:40%).

Levels were modified based on the works of Hapsari et al., (2022), Subamia et al., (2020), dan Pehulisa et al., (2016), and further adjusted by early experiments.

Penelitian ini merupakan penelitian eksperimental, menggunakan Rancangan Acak Lengkap (RAL) 1 (satu) faktor yaitu substitusi tepung ubi ungu dengan tepung ampas tahu dengan 5 taraf perlakuan : P0 (100%:0%); P1 (90%:10%), P2 (80%:20%), P3 (70%:30%) dan P4 (60%:40%) yang diulang sebanyak 3 (tiga) kali. Perlakuan ini didasarkan pada penelitian sebelumnya yang dilakukan oleh , yang telah dimodifikasi berdasarkan penelitian pendahuluan. The formulation of purple sweet potato flour flakes with tofu dregs flour substitution is presented in Table 1.

Table 1. Formulation of Purple Sweet Potato Flakes with Okara Flour Substitution

Formula	Treatment				
	P0	**P1**	**P2**	**P3**	**P4**
Purple Sweet Potato Flour (g)	100	90	80	70	60
Okara Flour (g)	0	10	20	30	40
Tapioca (g)	30	30	30	30	30
Sugar (g)	35	35	35	35	35
Salt (g)	4	4	4	4	4
Water (ml)	150	150	150	150	150

Preparation of Okara Flour

The procedure for making tofu dregs flour refers to the research of Fransiska dan Deglas, (2017), which has been modified based on preliminary research. The initial stage of the wet tofu dregs is squeezed using a cloth to reduce the water content, then steamed for 15 minutes at a temperature of 100ºC. The steamed tofu dregs are then dried in an oven for ±5 hours at a temperature of 65ºC while being turned over so that the tofu dregs dry evenly. The dried tofu dregs

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are then mashed using a blender and sieved using a flour sieve.

Flakes Processing

The procedure for making flakes refers to Susanti's research in Hapsari et al., (2022) which has been modified based on preliminary research. The initial process of making flakes is mixing purple sweet potato flour and tofu dregs flour according to the treatment (Table 1). After all the ingredients are combined, water is stirred until a smooth dough forms. The soft dough is then shaped like a long lontong sleeve and wrapped in aluminum foil. The dough is then steamed for 7 minutes at a temperature of 100°C, after which the dough is cooled at room temperature for 10 minutes to prevent the dough from sticking. The dough is then taken little by little to be flattened using a noodle maker with a thickness of ± 2 mm. The flattened dough is then molded into squares measuring 1cm × 1cm and arranged on a baking sheet for further baking. The baking process is carried out using an oven for 25 minutes at a temperature of 150°C.

Data Collection and Analysis

Flake texture data was obtained via physical testing. The flakes were placed on a flat surface and subsequently evaluated with a penetrometer. The penetrometer applied pressure to the flakes at a uniform velocity, and the depth of penetration was documented as an indicator of flake hardness (flake texture).

Data on rehydration capacity, which assesses the rate at which the flakes absorb water, was obtained by weighing samples of uniform mass, roughly 2.5 g each. The flakes were subsequently submerged in water at ambient temperature for 10 minutes. Upon completion of the soaking process, the flakes were extracted, drained, and subsequently weighed to assess the weight variation resulting from water absorption. The rehydration test results were computed using the formula: (weight of flakes after rehydration - weight of flakes before rehydration) / weight of flakes before rehydration, multiplied by 100.

Data regarding PANELIST preferences for the flakes were gathered from 30 semi-trained panelists, comprising professors, administrative personnel, and students from the Faculty of Vocational Studies at Untag Surabaya. The organoleptic evaluation encompassed color, flavor, fragrance, and texture, scoring from 1 to 5. A panelist assigned a score of 5 for "very liked," 4 for "liked," 3 for "moderately liked," 2 for "disliked," and 1 for "very disliked."

The gathered data were subsequently examined employing analysis of variance (ANOVA) at a 5% significance threshold utilizing SPSS 22 software. If discrepancies were identified, the Least Significant Difference (LSD) test was employed. The organoleptic data, being ordinal, were

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converted into interval data using the method of successive intervals (MSI) before ANOVA analysis.

3. RESULTS AND DISCUSSION

Texture (Penetrometer)

Texture critically affects consumer acceptance of flakes. Penetrometer readings (mm/100 g/10 s) are summarized below (means ± SD). Different letters indicate significant differences at 5%.. The results of the texture test using a penetrometer are presented in Table 2.

Table 2. Mean Texture of Flakes

Treatment	Mean (mm/100g/10 s)	Standard deviasi
P0	3.8000 a	1.52128
P1	3.6000 ab	1.24212
P2	3.4000 abc	0.82808
P3	2.8000 bc	1.14642
P4	2.6000 c	0.50709

Note: Mean values marked with different letters indicate a difference at the 5% level

Analysis of variance results showed that substituting purple sweet potato flour for tofu dregs flour significantly affected flake texture ($p = 0.016$). The higher the proportion of tofu dregs flour, the harder the flakes (lower the penetration value). The highest average penetration value was obtained in treatment P0 (100% purple sweet potato flour) at 3.80 ± 1.52. In comparison, the lowest value was found in treatment P4 (60% purple sweet potato flour: 40% tofu dregs flour) at 2.60 ± 0.51 (Table 2).

Further analysis using the Least Significant Difference (LSD) test showed that at the 5% significance level, treatment P0 was significantly different from treatments P3-P4, and treatment P1 was substantially different from treatment P4. However, no significant differences were found between the other treatments. These results indicate that substituting tofu dregs flour at 30% or more increases product hardness. The decrease in penetration value suggests that the higher the proportion of tofu dregs flour used, the more complex the texture of the resulting flakes. This is thought to be related to the high crude fiber and protein content in tofu dregs, resulting in a denser and stronger matrix structure after the baking process. This is in line with research conducted by

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Yuliani et al., (2020), which stated that high fiber and low water content due to the baking process tend to increase the hardness of flake products. The high protein content in tofu dregs also has the potential to form a stronger network, resulting in a more complex texture. Therefore, the percentage of added tofu dregs flour must be limited to maintain texture characteristics that suit consumer preferences.

Rehydration Capacity

Daya rehidrasi merupakan kemampuan produk kering (seperti flakes) untuk menyerap air kembali selama proses penyajian. Hasil uji daya rehidrasi disajikan pada Table 3.

Table 3. Rehydration Capacity of Flakes

Treatment	Mean (%)	Standard deviasi
P0	91.3111 a	7.63231
P1	102.0967 ab	9.59067
P2	104.7278 b	12.42594
P3	104.8611 b	13.59537
P4	124.0522 c	16.06680

Note: Mean values marked with different letters indicate a difference at the 5% level

The analysis of variance showed that substituting purple sweet potato flour with tofu dregs flour had a significant effect on the rehydration capacity of the flakes (p=0.000), with the average rehydration capacity increasing with the addition of tofu dregs flour. The treatment without tofu dregs (P0) showed the lowest average rehydration capacity, at 91.31%. In contrast, the treatment with the highest amount of tofu dregs substitution (P4) had the highest average rehydration capacity, at 124.05% (Table 3). This consistent increase indicates that tofu dregs flour positively increases the flakes' water absorption capacity.

Further investigation with the BNT test showed that the P4 treatment significantly differed from all other treatments (P0 to P3), while between treatments, P1, P2, and P3 showed no significant difference. The increase in rehydration power is not only influenced by starch content but also by the relatively high crude fiber content of tofu dregs flour, which is around 15-25% (Yuliani, 2012), while according to Suprapti in Pehulisa et al. (2016), the fiber content in purple sweet potato flour is around 4.72%. Crude fiber has the property of being able to capture water in the material, so that the baking process at high temperatures can cause evaporation of water in the product and leave air cavities that have the potential to create a porous structure in the flakes, thus

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allowing for greater water absorption (Anggi dan Putri, 2015). These results align with the research of Aristyarini et al., (2022), which states that fiber from tofu dregs has a high water absorption capacity to increase the product's rehydration power. Adding tofu dregs flour to a 40% substitution level significantly increased the rehydration capacity of the flakes. Therefore, further study is needed to determine the effect of this increased rehydration capacity on the texture and sensory acceptability of the product by consumers.

Sensory Evaluation.

Aroma

Aroma is an essential indicator of a food product, as it provides a distinctive characteristic of the ingredients used to make the product, thus influencing consumer preference (Kamalasari, 2019). Average panelist preference for flake aroma can be seen in Table 4.

Table 4. Panelists' Liking for Taste

Treatment	Mean	Standard deviasi
P0	3.3999	.95257
P1	3.6145	.95347
P2	3.4000	.94745
P3	3.3120	.95168
P4	3.3119	.91392

Note: Mean values marked with different letters indicate a difference at the 5% level

The analysis of variance indicated that substituting purple sweet potato flour with tofu dregs flour did not significantly affect the aroma of the flakes ($p = 0.725$). As the panelists assessed, incorporating tofu dregs flour at levels up to 40% did not substantially alter aroma. Table 4 indicates that the average aroma score for the five treatments varied between 3.31 and 3.61, placing them within the slightly preferred category. Treatment P1, comprising 90% purple sweet potato flour and 10% tofu dregs flour, achieved the highest score of 3.61, whereas treatments P3 and P4 recorded the lowest score of 3.31. This suggests that panelists generally offered consistent aroma evaluations across all treatments, with aroma preferences remaining stable despite the increase in the proportion of tofu dregs flour. This aligns with Setianingsih et al., (2018) which indicates that dried tofu dregs generate a neutral aroma that does not adversely impact the sensory quality of food products. Consequently, incorporating tofu dregs into the composition at levels up to 40% does not significantly disrupt the aroma of flakes, particularly when subjected to thermal

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processing methods such as baking, which can diminish compounds responsible for undesirable odors. Similarly, the findings of research by Rachmayani et al., (2017) indicated that an increase in the percentage of tofu dregs flour incorporated into purple sweet potato flour-based snack bar products correlates with a decrease in preference for the aroma; however, this difference is not statistically significant.

Taste

Taste is the most important indicator of consumer acceptance of a product (Irawan et al., 2017). Table 5 shows data on the average panelists' preference for the flake flavor.

Table 5. Panelists' Liking for Taste

Treatment	Mean	Standard deviasi
P0	3.7351 a	.93356
P1	3.6990 ab	.94892
P2	3.7553 a	.94819
P3	3.2270 bc	.96504
P4	2.7550 c	.95519

Note: Mean values marked with different letters indicate a difference at the 5% level

The analysis of variance (ANOVA) indicated that the substitution of purple sweet potato flour for tofu dregs flour had a significant impact on panelists' flavor preferences for the flakes (p=0.000). The treatment P2, comprising 80% purple sweet potato flour and 20% tofu dregs flour, achieved the highest average score of 3.76. In contrast, treatment P4, consisting of 60% purple sweet potato flour and 40% tofu dregs flour, recorded the lowest score of 2.76.

Subsequent BNT test results indicated that treatment P4 exhibited a significant difference compared to treatments P0 to P2, while no significant difference was observed compared to P3. Increasing the tofu dregs flour content by 40% significantly reduced panelists' preference for the flavor. Koswara in Rahmiati et al., (2021) indicates that incorporating tofu dregs into processed food products can elevate the concentrations of compounds responsible for undesirable odors, bitterness, and astringency, attributed to the increased presence of off-flavor compounds, including glucosides, saponins, and estrogens. The average scores for treatments P0 to P2 were nearly identical, exhibiting no statistically significant differences. Incorporating up to 20% tofu dregs did not significantly diminish taste quality and was well accepted by the panelists. The score decline was first observed in treatment P3 (70% purple sweet potato flour: 30% tofu dregs flour),

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suggesting that adverse effects on taste emerged when the proportion of tofu dregs surpassed 20%.

Texture (Crispness)

Sebaran data rata-rata kesukaan panelis terhadap tekstur (kerenyahan) flakes dapat dilihat pada Table 6.

Table 6. Panelists' Liking for Texture

Treatment	Mean	Standard deviasi
P0	3.9396 a	.94504
P1	3.8550 a	.95168
P2	3.9394 a	.87415
P3	3.9399 a	.92517
P4	2.7549 b	.97017

Note: Mean values marked with different letters indicate a difference at the 5% level

The analysis of variance (ANOVA) indicated that the substitution of purple sweet potato flour for tofu dregs flour significantly impacted panelists' preference regarding the texture (crispness) of the flakes ($p=0.000$). Treatment P4 exhibited the lowest panelist preference score for flake texture, recorded at 2.7549, whereas the other treatments (P0 to P3) presented comparable scores ranging from 3.8 to 3.9.

Subsequent analysis with the LSD test indicated that treatment P4 differed significantly from all other treatments (P0, P1, P2, and P3), while no significant differences were found among treatments P0, P1, P2, and P3. Incorporating tofu dregs up to 30% did not significantly diminish the panelists' preference for the texture of the flakes. The panelists' preference for texture significantly decreased when the proportion of tofu dregs reached 40% (treatment P4). This finding is consistent with the research conducted by Suryani et al., (2018), which indicated that an increase in the proportion of tofu dregs in biscuit formulations led to a significant reduction in texture scores when the tofu dregs flour surpassed 40%. The decrease in scores for treatment P4 can be attributed to the elevated crude fiber content of the tofu dregs, which may lead to a rougher, harder, or less crunchy texture. Treatment P4 exhibited a less homogeneous and more fragile flake structure, thereby not satisfying panelists' criteria for the optimal texture of cereal flakes, which include characteristics such as crunchiness, lightness, or density without hardness. Kasim et al., (2018) indicates that significant water evaporation elevates total soluble solids, potentially resulting in a complex and compacted texture.

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Treatments devoid of tofu dregs (P0) and those incorporating 10–30% tofu dregs (P1, P2, P3) exhibited textures deemed acceptable by panelists. This is likely attributable to the stable equilibrium between the fiber structure and the bonds within the flour matrix. Yuliani & Mardesci (2017) demonstrated that substituting up to 30% tofu dregs in biscuit production maintains a preferred texture, suggesting a sensory tolerance limit for crude fiber content at 30%.

Color

Color is the primary indicator for evaluating a product; attractive colors typically lead to higher consumer preference (Kamalasari, 2019) Table 7 shows data on the panelists' average preference for the color of the purple sweet potato flour substitution flakes with tofu dregs flour.

Table 7. Panelists' Liking for Color

Treatment	Mean	Standard deviasi
P0	3.2272 a	.95873
P1	3.7549 b	.93318
P2	3.7549 b	.95073
P3	3.9397 b	.93868
P4	3.9393 b	.93819

Note: Mean values marked with different letters indicate a difference at the 5% level

Results from the variance analysis indicated that the substitution of purple sweet potato flour for tofu dregs flour significantly influenced panelists' preference regarding flake color ($p = 0.025$). The average preference score for flake color increased with a higher proportion of tofu dregs. Treatments P3 and P4, which utilized purple sweet potato flour to tofu dregs flour ratios of 70:30 and 60:40, respectively, attained the highest score of 3.94. In contrast, treatment P0, consisting of 100% purple sweet potato flour, recorded the lowest color score of 3.23.

Subsequent LSD testing indicated that P0 exhibited a significant difference from all other treatments (P1 to P4), whereas the differences among P1, P2, P3, and P4 were not substantial. Flakes made exclusively from purple sweet potato without tofu dregs substitution (P0) were generally less favored in color. In contrast, the panelists noted that including tofu dregs at levels between 10% and 40% resulted in a more visually appealing color. Tofu dregs flour exhibits an ivory white hue, which enhances the visual brightness of the flakes compared to P0 (without tofu dregs substitution). This is attributed to its higher anthocyanin pigment content relative to purple sweet potato flour, which produces a darker purple color. Furthermore, the baking process

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facilitates the Maillard reaction between the protein in tofu dregs and sugars from other ingredients, resulting in a desirable light brown color noted by the panelists (Winarno, 2004). The flakes in the P0 treatment exhibit an excessively dark purple hue. In contrast, incorporating tofu dregs results in a lighter purple color with a subtle brownish tint post-baking, enhancing the visual appeal of the flakes product..

4. CONCLUSION

The replacement of purple sweet potato flour with tofu dregs flour significantly influenced the physical properties and texture ($p = 0.016$) as well as the rehydration capacity of the flakes ($p < 0.001$). An increase in the proportion of tofu dregs flour resulted in a firmer texture and enhanced rehydration ability of the flakes. The replacement of purple sweet potato flour with tofu dregs flour significantly influenced the panelists' preferences regarding taste ($p = 0.000$), texture ($p = 0.000$), and color of the flakes ($p = 0.025$), while showing no significant effect on aroma ($p = 0.725$). As the substitution of tofu dregs flour increased, the taste and texture of the flakes were generally less favored. Conversely, regarding color, a higher substitution of tofu dregs flour resulted in a greater preference for the flakes' color. The optimal flakes were identified with a 20% substitution of tofu dregs flour.

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