Journal of Food Technology Research
2026 Vol. 13, No. 3, pp. 100-114
ISSN(e): 2312-3796
ISSN(p): 2312-6426
DOI: 10.18488/jftr.v13i3.5181

Physicochemical and sensory properties of purple sweet potato brownies prepared with autoclave–cooling cycle modified flour

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Article History
Received: 18 May 2025
Revised: 25 May 2026
Accepted: 19 June 2026
Published: 14 September 2026

Keywords
Autoclave-cooling cycle
Brownies
FTIR
Modified flour
Purple sweet potato
Sensory
Texture profile analysis.

ABSTRACT

This study aimed to determine the effect of the type and concentration of modified flour produced through the autoclave–cooling cycle (ACC) process on the physicochemical and sensory properties of purple sweet potato brownies as an alternative to wheat-based products. The research was conducted in two stages, including raw material preparation and analysis, followed by brownie formulation using three types of ACC-modified tuber flours (cassava, purple sweet potato, and suweg) at concentrations of 2%, 4%, and 6% in a randomized block design with a 3 × 3 factorial arrangement. Physicochemical properties, starch content, texture characteristics, FTIR spectra, and sensory attributes were analyzed to evaluate product quality. The results indicated that three autoclave–cooling cycles did not alter the fingerprint region conformation of the starch structure compared with native sweet potato flour. The type and concentration of modified flour showed no significant effect on color, aroma, moisture content, hardness, adhesiveness, and cohesiveness of the brownies ($p > 0.05$), while significant differences were observed in taste and starch content ($p < 0.05$). The best formulation was obtained from brownies containing 6% ACC-modified sweet potato flour, achieving the highest overall score (39.37). The selected product contained 16.21% moisture, 1.28% ash, 3.53% protein, 29.42% fat, 49.56% carbohydrate, and 9.06% dietary fiber, meeting general brownie quality standards. These findings demonstrate the potential application of ACC-modified tuber flours as functional ingredients in bakery products, supporting wheat flour substitution and promoting the utilization of local carbohydrate sources for the development of high-fiber and potentially lower-calorie food products.

Contribution/Originality: This study contributes to the existing literature by examining the application of autoclave–cooling cycle-modified tuber flours as wheat flour substitutes in purple sweet potato brownies. The paper's primary contribution is finding that modified tuber flours can produce brownies with comparable quality and higher dietary fiber content.

1. INTRODUCTION

The Indonesian community has been very dependent on wheat consumption. Wheat flour consumption in Indonesia in 2023 was 2.94 kilograms per capita per year, an increase of 6.73% from the previous year. In 2020, 2021, 2022, and 2023, the volume of wheat imports reached 10.29, 11.17, 9.46, and 10.87 million tons, respectively, which will continue to increase over time (Statistics Indonesia, 2024).

Consumption of wheat flour with high gluten levels of 8-14% is indicated to cause various diseases, viz., autism, celiac, attention deficit, digestive disorders, and various degenerative diseases. The dependency on raw wheat materials to process food products will also divert attention from the benefits of local plants that can replace wheat flour (Winarti, Arif, Budiyanto, & Richana, 2020). Food diversification based on local non-wheat products is therefore essential. Sweet potatoes (*Ipomoea batatas* (L.) Lam.) are among the easiest tubers to grow. Sweet potatoes have garnered more attention in recent years to diversify the diet based on local non-wheat items due to their valuable properties. One of the simplest tubers to grow is the sweet potato (*Ipomoea batatas* (L.) Lam.). Sweet potatoes' functional qualities have drawn attention in recent years (Wang, Nie, & Zhu, 2016). A valuable source of carbs, antioxidants, and bioactive substances is sweet potato flour (Bach, Bedin, Lacerda, Nogueira, & Demiate, 2021). Purple sweet potato is a type of vegetable that is highly nutritious, has a high anthocyanin content, and contains polysaccharides (Wu et al., 2015).

Nowadays, many modifications are made to the flour variation because it is believed that the modification process could produce better properties than its original features. The autoclaving-cooling cycle approach is one of several possible flour modifications. Increasing resistant starch levels and decreasing starch digestibility are two benefits of the autoclaving-cooling cycle approach (Lehmann, Jacobasch, & Schmiedl, 2002; Leong, Karim, & Norziah, 2007; Zhao & Lin, 2009). Resistant starch can be utilized as a low-calorie food ingredient because of its low calorific value (Bauer, Wiehle, & Knorr, 2005). Starch retrogradation, which happens when the gelatinized starch is kept at low temperatures, creates resistant starch during autoclaving cooling. According to earlier research, the autoclaving chilling procedure frequently results in the formation of more retrograded starch, which is a low-calorie food ingredient with a low calorific value (Bauer et al., 2005). When the gelatinized starch is kept at low temperatures, a process known as starch retrogradation takes place, forming resistant starch during autoclaving and cooling. According to earlier research, the autoclaving chilling procedure consistently results in the formation of more retrograded starch, as seen by the rising resistant starch levels (Nasrin & Anal, 2014). According to the findings of multiple investigations, food processing products have hardly ever undergone this kind of change (Sajilata, Singhal, & Kulkarni, 2006).

The majority of prior research has mainly concentrated on the structural and physicochemical modification of starch rather than its useful application in food products, despite the growing interest in resistant starch production through autoclave–cooling cycle (ACC) treatment (Nasrin & Anal, 2014; Rahman, Andriansyah, Luthfiyanti, Surahman, & Triyono, 2025). More significantly, only a small number of studies have assessed the physicochemical and sensory characteristics of ACC-modified flours in complex food matrices such as baked goods. Brownies are one of the most popular foods in Indonesia, and they are favored by various age groups and social statuses. Brownies consist of 2 types, viz., baked and steamed brownies. According to Isaskar, Darwanto, Waluyati, and Irham (2021), it was shown that there was no difference in preference for the taste of brownies made from modified cassava flour and wheat flour, while there were significant differences in terms of color, aroma, and texture. Brownies made using purple sweet potato flour had a thick texture and could not expand. However, no research has been conducted on purple sweet potato brownies with additional modified flour produced from the Autoclaving-cooling cycle; therefore, it is necessary to research the effect of the type and concentration of modified flour produced from the Autoclaving-cooling cycle on the characteristics of sweet potato (non-wheat) brownies. In order to close this gap, this study compares the impact of various ACC-modified tuber flour types and concentrations on the physicochemical and sensory properties of purple sweet potato brownies. It is anticipated that the study's findings will serve as a guide for the variety of modified tuber flour processed goods made using the autoclaving-cooling cycle.

1.1. Literature Review

The autoclave–cooling cycle (ACC) has been extensively researched as a physical modification method to improve the functional qualities of starch-based components by increasing resistant starch (RS) content through starch retrogradation. According to recent research, ACC treatment can dramatically raise resistant starch levels and alter the crystalline structure of starch granules, improving their durability and usefulness in food systems (Oktaviani, Faridah, Wulandari, Afandi, & Jayanegara, 2023; Xu et al., 2023).

According to earlier research, ACC modification can change the physicochemical characteristics of starch, such as its crystalline structure, pasting qualities, and gelatinization behavior, which may have an impact on how it is used in food processing. Because resistant starch has a lower digestibility and glycaemic response, it can be used to create functional and low-calorie food products. This has drawn attention to the formation of resistant starch through autoclaving and cooling treatment (Faridah et al., 2022; Surawan, Harmayani, Nurliyani, & Marseno, 2024). However, rather than assessing the effectiveness of ACC-modified flour in intricate food systems like baked goods, the majority of earlier research has mostly concentrated on starch characterisation or resistant starch production. Furthermore, resistant starch stability and the ultimate nutritional quality of baked goods may be impacted by thermal processing like baking (Gutiérrez-Luna, Ansorena, & Astiasaran, 2024; Puspawati, Adyeni, & Setiarto, 2024). Therefore, further research is required to evaluate the practical application of ACC-modified tuber flours in bakery formulations and to determine their effects on the physicochemical and sensory properties of food products.

2. DATA AND METHODOLOGY

The autoclave cooling cycle technique was adapted to modify sweet potato, cassava, and cassava flour. This study investigates the application of the autoclave, cooling cycle (ACC) modified tuber flours in brownie formulations as wheat flour substitutes. The study hypothesizes that the incorporation of ACC-modified tuber flours will significantly influence the moisture content, starch content, texture, and sensory characteristics of brownies, and that appropriate flour type and concentration can produce brownies with acceptable quality comparable to conventional wheat-based products.

2.1. Materials

The material used in this study is purple sweet potato flour (*Ipomoea batatas* var. *Ayamurasaki*- MSU 03028-10), modified cassava flour, modified sweet potato flour, and modified suweg (*Amorphophallus campanulatus* var. *Hortensis*) flour, which was made at the Postharvest Laboratory, Research Center for Appropriate Technology, National Research and Innovation Agency, Indonesia. Dark cooking chocolate, butter, sugar, eggs, cocoa powder, skimmed milk powder, vegetable oil, salt, water, and baking powder were bought from Modern Market in Subang City, West Java, Indonesia. For the analysis, H_2SO_4, 45% NaOH, 1% NaOH, 30% NaOH, phenolphthalein indicator, 25% HCl, 4 N HCl, 1 N HCl, 0.01 N HCl, Na2S2O3, Kjeldahl salts, boiling stone, n-hexane, cotton, tin, petroleum benzene, distilled water, Luff-Schoorl, KI, and 1-dipheynl-2-picrhyidrazil (DPPH).

2.2. Sample Preparation

Andriansyah, Rahman, Herminiati, Rahman, and Luthfiyanti (2017) used to produce modified cassava flour. Tuber flour suspended in water is used to make flour modified by an autoclaving-cooling cycle. The suspension was heated to 121°C in an autoclave after being gelatinized at 70–85°C. The suspension was then allowed to cool for four to five hours at room temperature before being frozen for twelve to sixteen hours at 4°C. After utilizing a cabinet dryer to dry the suspension to a moisture content of 12%, grinding and 70 mesh filtering were done.

Brownie's preparation was done according to Lubis, Nurminah, and Nainggolan (2021) with modifications to the ingredient formulation. Weigh all the ingredients according to the formulation, then add the margarine and the sugar, and stir until homogeneous for 5 mins. The baking powder, salt, and eggs are added, then stirred until fluffy for 5 mins. For seven minutes, the modified flour and purple sweet potato flour were added gradually until they were evenly distributed. Three varieties of modified flour (a1 = cassava flour, a2 = sweet potato flour, and a3 = suweg flour) with concentrations of b1 = 2%, b2 = 4%, and b3 = 6% were employed. The dough was combined with liquid chocolate, water, and vegetable oil, swirled for five minutes, then placed into a brownie mold measuring 10 cm by 30 cm by 4 cm. It was then mashed and cooked for 25 minutes at 160 °C.

2.3. Experimental Design

A Randomized Block Design (RBD) with a 3×3 factorial pattern and three repeats was used for the main study. Two factors were used in these stages: factor A represented the modified flour (a1 = Cassava flour, a2 = Sweet potato flour, and a3 = Suweg flour), while factor B represented the powder content (b1 = 2%, b2 = 4%, and b3 = 6%).

2.4. Procedure Analysis

2.4.1. Moisture Content

A Moisture Analyzer (TOVATECH; model DSC 71P) was used to measure the moisture content of the flour and brownies. After being weighed, five grams of the sample were put on an aluminum pan. At 25°C, the samples' moisture content was reported in triplicate as a percentage (%) (AOAC, 2006). The heating temperature was set at 160°C by the manual's standard.

2.4.2. Starch Content

An enzymatic colorimetric approach was used to estimate the total amount of starch (AOAC, 2006). After about 100 mg of the material was added to a test tube, 2 mL of an ethanol solution (80% v/v) was added. The tubes were then cooked for 6 minutes and swirled for 2 minutes after 3.0 mL of thermostable α-amylase was added right away. After that, tubes were left to rest for five minutes in a bath at 50°C. Amyl-glucosidase (0.1 mL) was then added to each tube. After 30 minutes of incubation with occasional mixing, tubes were brought to 10 mL with distilled water and centrifuged at 1,800×g for 10 minutes at room temperature. Finally, 1.0 mL aliquots of the supernatant were taken and diluted as required for analysis.

2.4.3. Physical Properties

A texture analyzer model TA-XT2 (Stable MicroSystems Ltd., Surrey, England, UK) was used to examine the physical attributes of hardness (N), cohesiveness, and adhesiveness (Ns) (Lukman, Huda, & Ismail, 2009).

2.4.4. Fourier Transform Infrared

FTIR analysis was performed on flour samples. An FTIR spectroscope (Bruker A7.8) was used to load the samples directly, and each sample was scanned three times with a scan range of 500 to 4000 cm^{-1} (Iwansyah et al., 2021).

2.4.5. Sensory Test

The sensory test was carried out by hedonic testing using the scoring method (Solichah et al., 2022). An organoleptic test was performed on 30 untrained panelists at the Research Center for Appropriate Technology, BRIN. Panelists were given nine brownie samples and asked to rank their likeliness on color, texture, taste, and smell on a 5-level scoring method, in which 1 is (extremely dislike) to 5, which is (extremely like).

2.5. Statistical Analysis

Mean ± standard deviation (SD) was used to display the data (n = 3). Analysis of variance (ANOVA) was utilized to determine the significant differences between treatments following a normality test. Duncan's New Multiple Range Test (DMRT) was used after ANOVA to find particular pairwise differences at a 95% confidence level. For statistical analysis, Microsoft Excel 365 and R-Statistics for Windows 4.0.3 were utilized (de Mendiburu, 2019).

3. FINDINGS

3.1. Modified Flour

The results of the autoclaving-cooling cycle process showed that the yield of modified flour of cassava, suweg, and sweet potatoes was 61.87%, 48.05%, and 76.65%, respectively. Proximate analysis of the native purple sweet potato flour showed that the content of moisture, ash, protein, fat, carbohydrate, antioxidant activity, and fibre of native purple sweet potato flour was 5.58%, 2.32%, 2.52%, 0.35%, 80.41%, 8.70 ppm, and 4.67%, respectively. The content of moisture of modified flour of cassava, suweg, and sweet potato was 7.44%, 7.37%, and 7.47%, respectively. Their ash content was 1.78%, 2.29%, and 2.49%, respectively. Their protein content was 2.76%, 5.12%, and 2.15%, respectively. Their fat content was 0.1%, 0.24%, and 0.06%, respectively. Their carbohydrate content was 85.34%, 84.9%, and 87.85%, respectively, and their fibre content was 2.48%, 0.13%, and 7.47%, respectively. The interval plot of the proximate content of native purple sweet potato flour, modified cassava flour, suweg, and sweet potato is presented in Figure 1.

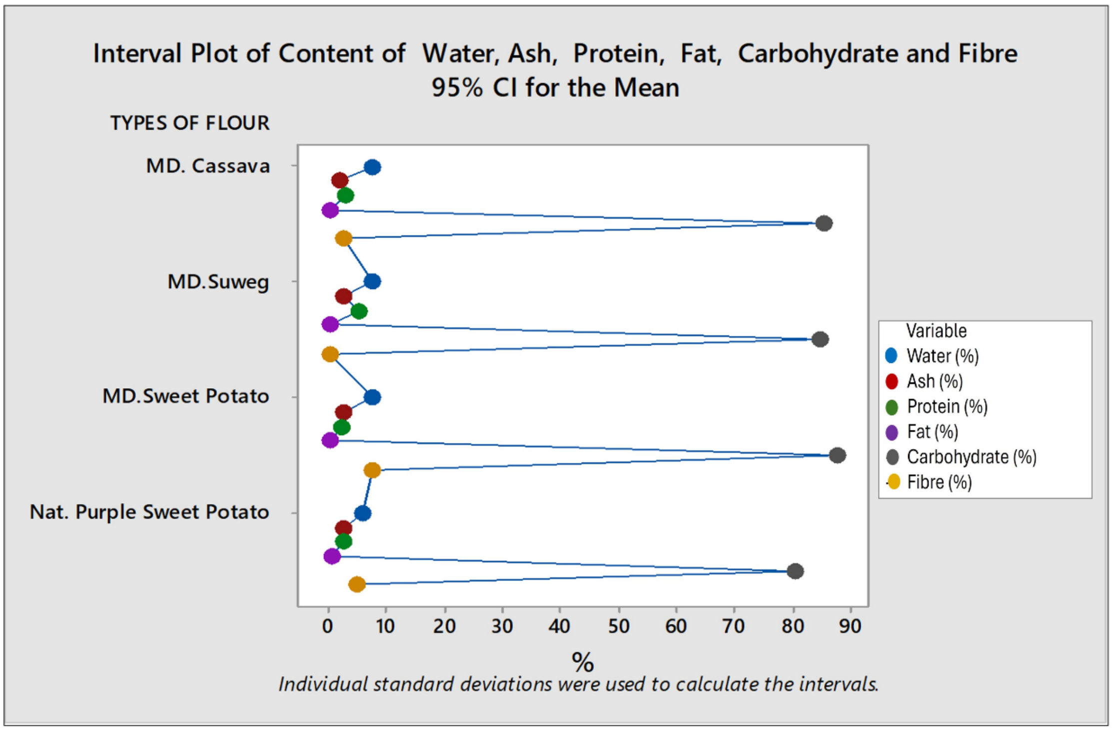
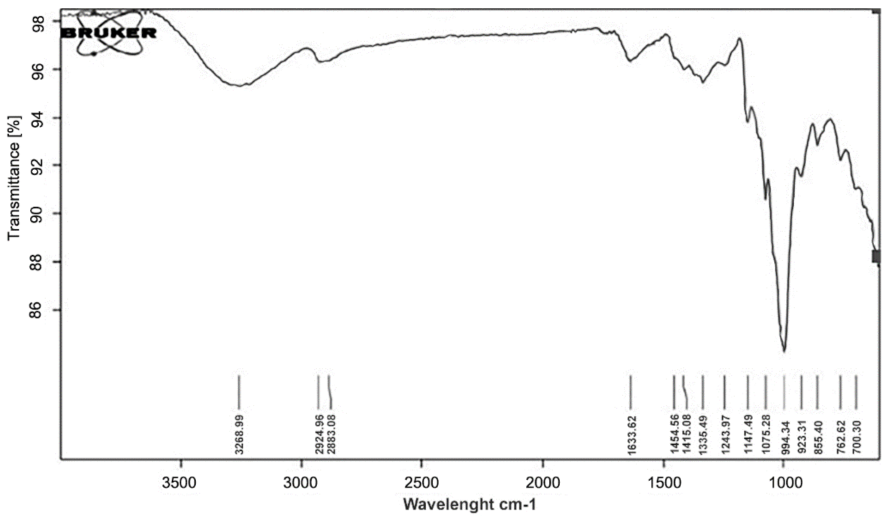
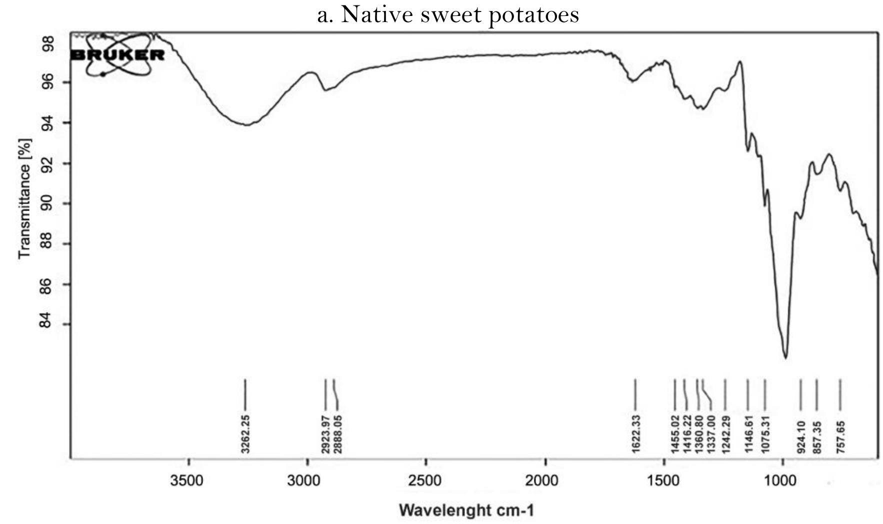


Figure 1. The interval plot of the content of the proximate elements of native purple sweet potato flour and modified flour of cassava, suweg, and sweet potato.

Below 800 cm−1, 500 cm−1 (the fingerprint region), 2,800–3,000 cm−1 (the C–H stretch region), and, lastly, 3,000–3,600 cm−1 (the O–H stretch region) were the places where the FTIR spectra were displayed. For the uncooked sweet potato, the O-H stretching was 3322.15 cm-1. The C–H bond stretching caused the peaks at 2928.10 cm-1 to be seen (Ajayi et al., 2019). The FTIR spectrum of sweet potato (Figure 2a) exhibits a broad absorption band at approximately 3289 cm^{-1}, which is attributed to the stretching vibration of hydroxyl (O–H) groups, primarily associated with carbohydrate constituents. The absorption bands at 2924 and 2853 cm^{-1} correspond to the asymmetric and symmetric stretching vibrations of aliphatic C–H groups. The band observed at 1633 cm^{-1} is assigned to the bending vibration of molecularly bound water within the starch matrix. Furthermore, the prominent absorption bands in the 1200–1000 cm^{-1} region (1243, 1147, 1075, and 1032 cm^{-1}) are characteristic of C–O and C–O–C stretching vibrations, which are indicative of polysaccharide structures. These spectral features collectively confirm that starch is the predominant component in sweet potato. The FTIR spectra of sweet potato modified through autoclaving (Figure 2b) showed no formation of new functional groups compared to the native sample, indicating that the modification process was primarily physical in nature. However, changes in band intensity and slight shifts in the O–H stretching region (~3262–3300 cm^{-1}), as well as in the C–O stretching region (1200–1000 cm^{-1}), suggest structural alterations within the starch matrix. These spectral changes are indicative of starch gelatinization during autoclaving, followed by retrogradation upon cooling, which promotes the rearrangement of starch chains. Consequently, this process contributes to the formation of more ordered structures, commonly associated with resistant starch in the modified sample.



a. Native sweet potatoes



b. Modified sweet potatoes

Figure 2. The FTIR spectra of (a). native sweet potatoes and (b). modified sweet potatoes.

3.2. Moisture Content

The moisture content of purple sweet potato brownies ranged from 16.21-18.83%. The moisture content of modified cassava, sweet potato, and suweg (*Amorphophallus campanulatus*) powders was 7.44%, 7.47%, and 7.37%, respectively. A time series plot of the moisture content of the purple sweet potato brownies is presented in Figure 3.

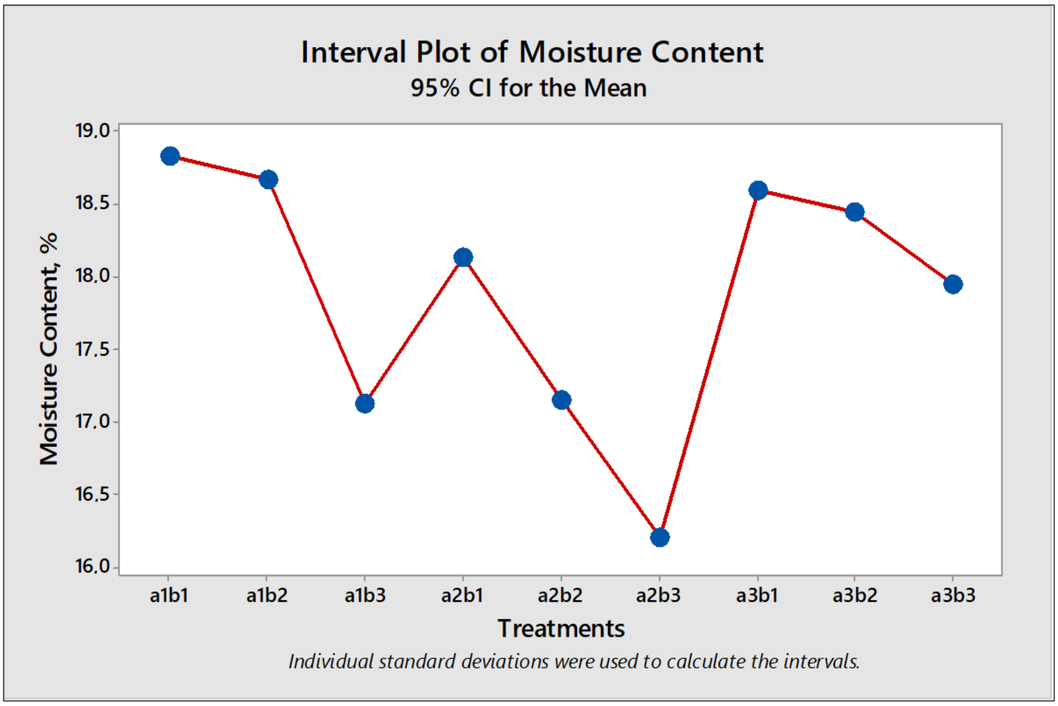


Figure 3. The Moisture content of purple sweet potato brownies in various treatments.

3.3. Starch Content

The starch content of purple sweet potato brownies ranged from 6.70% -12.79%. Based on the results of variance analysis of the starch purple sweet potato brownies, the type of modified flour, the concentration of modified starch, and the interaction between the two significantly affected the purple sweet potato flour. The time series plot of starch content of the purple sweet potato brownies is presented in Figure 4.

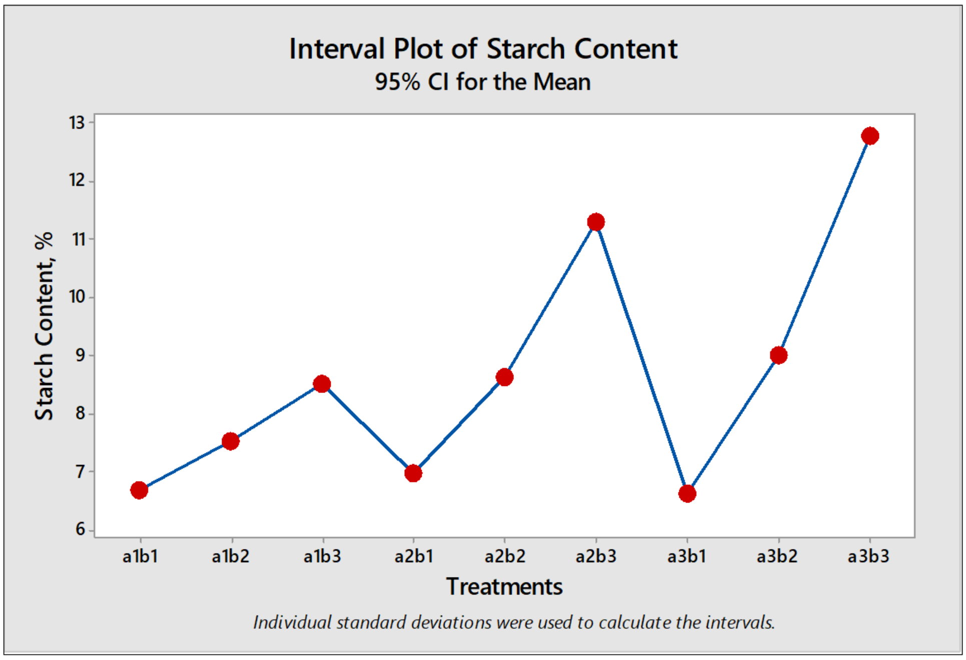


Figure 4. The Starch content of purple sweet potato brownies in various treatments.

Table 1 shows the results of Duncan's test analysis at a 95% confidence interval of the difference showed that the interaction between the ratio and concentration of flour produced by the Autoclave-Cooling Cycle process increased significantly along with the addition of modified flour concentration. The resulting brownies had a different starch content; this was due to the starch sources of the ingredients used, which were also significantly different. The starch content of modified cassava, purple sweet potato, and suweg was 67.31%, 76.09%, and 77.22%, respectively.

Table 1. Effect of interaction between types and concentrations of modified flour against the starch levels of purple sweet potato brownies.

Types of modified flour	The Concentration of modified flour		
	B1 (2%)	B2 (4%)	B3 (6%)
A1 (Cassava)	6.70±0.34^{Aa}	7.54±0.49^{Aa}	8.52±0.50^{Ab}
A2 (Purple Sweet potato- Ayamurasaki- MSU 03028-10)	6.89±0.20^{Ab}	8.64±0.74^{Bb}	11.31±0.29^{Bc}
A3 (Suweg- Amorphophallus campanulatus)	6.62±1.08^{Aa}	9.01±0.90^{Bb}	12.79±0.34^{Cc}

Note: Data are presented as mean. a<b<c, Values in the same columns followed by different alphabets are significantly different by Duncan's test (p<0.05). Letter uppercase (Type of modified effect) and lowercase (Concentration modified effect).

3.4. Hardness

The hardness value of purple sweet potato brownies ranged from 1103.45 to 1703.80 g-forces. Results of variance analysis of purple sweet potato brownies showed that the type and concentration of modified flour and the interaction between both had no significant effect on the purple sweet potato brownies. The insignificant impact was due to the protein content of each modified starch being no different, except for modified suweg starch. The amount of protein content of modified flour of cassava, purple sweet potato, and suweg was 2.76%, 2.15%, and 5.12%, respectively. A time series plot of the starch content of the purple sweet potato brownies is presented in Figure 5.

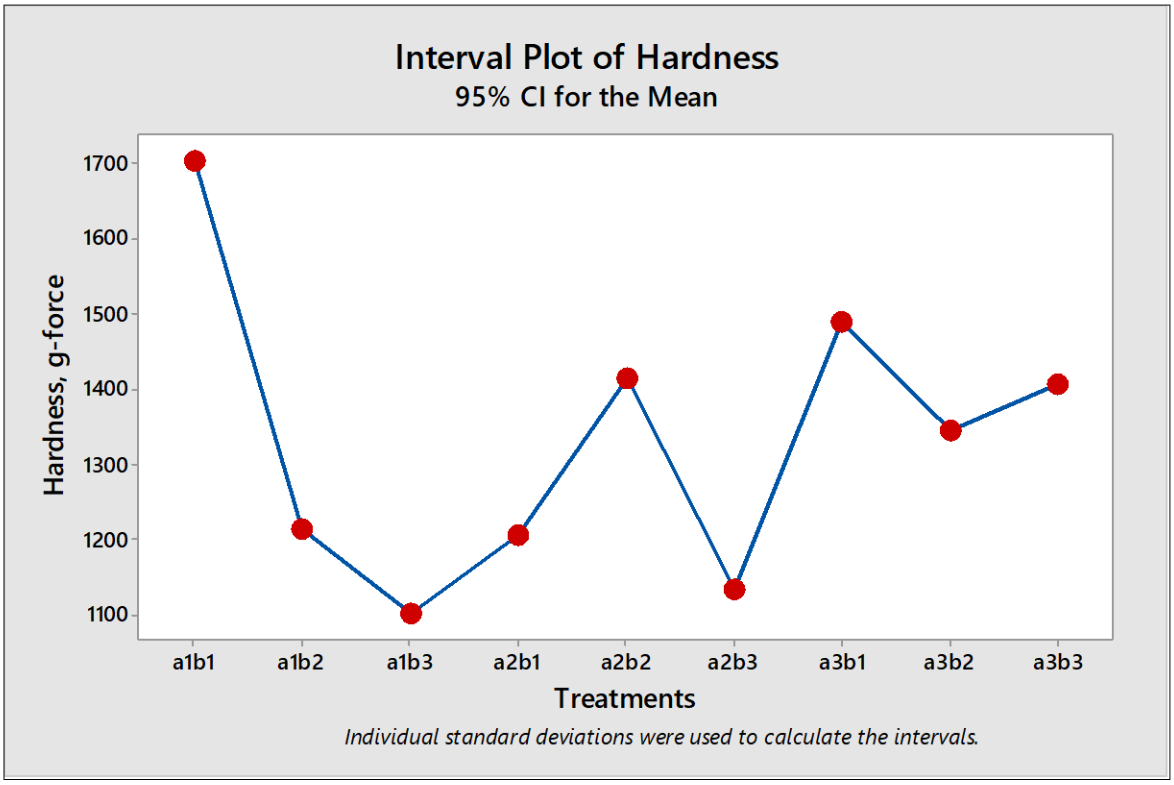


Figure 5. The hardness of purple sweet potato brownies.

3.5. Adhesiveness

Figure 6 illustrates the purple sweet potato brownies' adhesiveness. The value of adhesiveness of purple sweet potato brownies ranged from -97.218 to 68.659 g-force. Results of variance analysis showed that the type, concentration, and interaction between them did not significantly affect the purple sweet potato brownies. The insignificant difference allegedly was caused by the amylose content of the starch-modified starch, respectively, which was not much different.

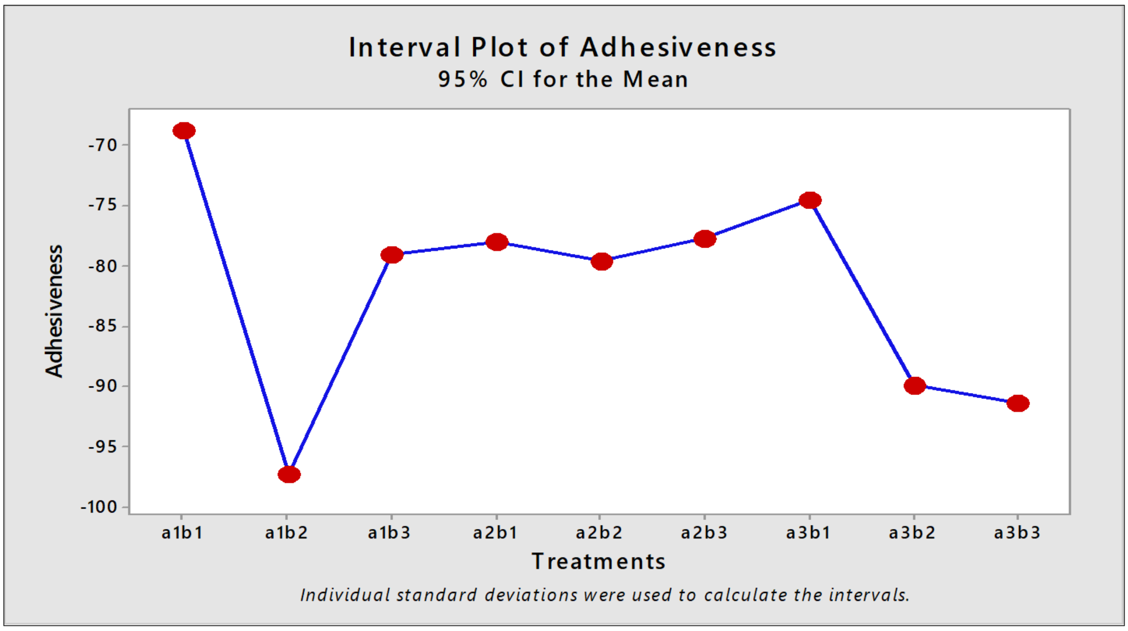


Figure 6. The adhesiveness of purple sweet potato brownies.

3.6. Cohesiveness

The ratio of the second compression's work area, that is, the area of work during the second compression divided by the area of work during the first compression, was known as cohesiveness. Brownies had cohesion values between 0.393 and 0.466. Figure 7 shows how cohesive the purple sweet potato brownies are. The results of variance analysis showed that the type, concentration, and interaction between the type and concentration of the modified purple sweet potato flour had no significant effect on purple sweet potato brownies. The insignificant difference occurred because the modified cassava, purple sweet potato, and suweg flours had a different character from the wheat flour.

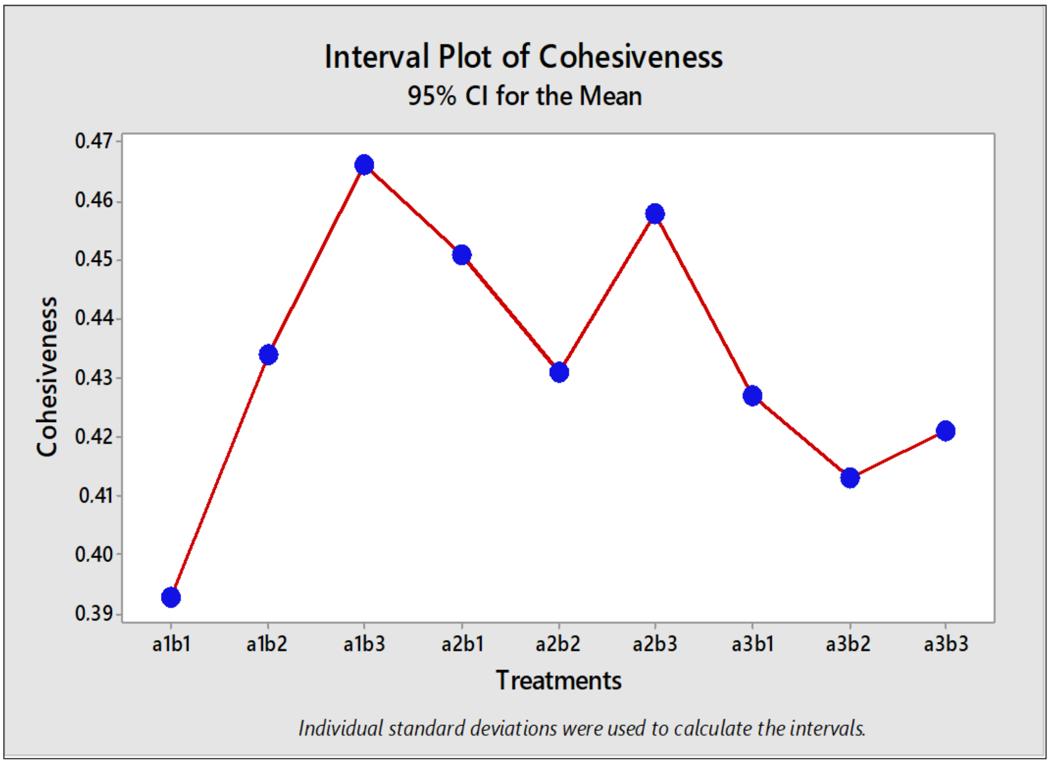


Figure 7. The cohesiveness of the purple sweet potato brownies.

3.7. The Best Formulation

The method used to select the best sample in this study was the scoring method (Table 2). The criteria used to determine the score consisted of an organoleptic, chemical, and physical response to the sample. The highest sample value showed the best sample. The results of the proximate analysis of the best sample are presented in Table 3.

Table 2. The organoleptic, chemical, and physical responses to various treatments.

Treatments	Responses			Scores
	Organoleptic	Chemical	Physical	
a1b1	17.81	2	8	26.81
a1b2	17.07	2	10	25.07
a1b3	16.63	6	16	32.63
a2b1	17.54	3	15	30.54
a2b2	16.89	6	10	29.89
a2b3	17.37	11	16	39.37
a3b1	17.33	2	11	27.33
a3b2	16.42	4	8	26.42
a3b3	16.02	9	8	30.02

Table 3. The proximate composition of the best sample.

Parameter	Value
Water (%)	16.21
Ash (%)	1.28
Protein (%)	3.53
Fat (%)	29.42
Carbohydrate (%)	49.56
Fiber (%)	9.06

The quality standard of brownies and purple sweet potato brownies did not significantly differ from one another, according to the findings of the paired test sample, which are shown in Table 4. As a result, the purple sweet potatoes satisfied the brownie quality standards.

Table 4. A paired test sample between the quality standard of brownies and purple sweet potato brownies.

	Paired Differences					t	df	Sig.
	Mean	Standard Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pairs	-3.7183	7.8792	3.2167	-11.9870	4.5504	-1.156	5	0.300

4. DISCUSSION

4.1. Modified Flour

The yield of modified cassava flour is higher compared to the study by Kardhinata, Purba, Suryanto, and Rusmarilin (2019), which ranged between 33% and 38%. Similarly, the yield of modified suweg flour is higher than the results from the study by Permadi and Wulandari (2023). The yield of tuber flour was influenced by the type, variety, age, maturity, and surface area of the tuber, the amount of water contained in the raw material, and the method of processing. Processing of raw materials that did not follow standard operating procedures, as well as processing losses, also affected the yield (Stapelbroek, Kilic, Yang, & Van Donk, 2024).

The study found that modified purple sweet potato flour had higher moisture, ash, carbohydrate, and fiber content, while protein and fat levels decreased. The decrease in protein and fat was due to gelatinization followed by autoclaving, while increased moisture resulted from water absorption during gelatinization. The fiber content was also higher than that of native purple sweet potato flour (2.57%), as reported by Rodrigues, Barbosa Junior, and

Barbosa (2016). FTIR test results showed that the uncooked sweet potato contains chemicals from the hydroxyl, hydrocarbon, and aldehyde groups. Compared to the fingerprint region, the alteration autoclaving cooling three cycles did not alter the fingerprint region's conformation.

4.2. Chemical Analysis

This study found lower moisture content in brownies compared to Peñalver, Martínez-Zamora, Lorenzo, Ros, and Nieto Martínez (2024), which ranged from 42.26% to 47.08%. Sumartini, Harahap, and Mujiyanti (2020) reported moisture content between 14.74% and 24.51%, depending on the raw materials. The drying method can have a significant effect on the moisture content of sweet potato flour (Olatunde, Henshaw, Idowu, & Tomlins, 2016). The water was analysed to determine the moisture content of free and adsorbed water contained in the material. Results of variance analysis showed that the type of modified flour, concentration, and the interaction between them had no significant effect on purple sweet potato brownies, because the water content of each modified flour did not have too much difference. According to Winarno (2008), the amount of water added during the process of making brownies also affected the final moisture content of the product. The long process of baking brownies caused the water contained in the brownies to evaporate.

Brownies with the addition of modified suweg starch produced the highest starch content; this was due to modified suweg starch containing the highest starch compared to that of other modified starches. According to Singh, Kaur, and McCarthy (2007) the total starch content is influenced by the type of material, but not by the modification process. Starch content was not affected by the modification process, allegedly because of the measurability of resistant starch as a part of starch other than amylose and amylopectin. Besides amylose and amylopectin, modified starch (Resistant starch) is also included as a starch component.

4.3. Physical Analysis

The results of research conducted by Selvakumaran, Shukri, Ramli, Dek, and Ibadullah (2019) showed that the hardness value of brownies made from orange sweet potato puree ranged from 1213.63 to 3361.3 g-forces. This shows that different types of raw materials used can contribute to differences in texture parameters. According to Selvakumaran et al. (2019), the protein levels affect the hardness of brownies. The texture of food was determined mainly by the amount of water and fat content, and the type of carbohydrates and proteins (Fellows, 2000). The insignificant moisture and fat content, and a variety of carbohydrates and proteins, caused a negligible effect on the hardness of purple sweet potato brownies.

Adhesiveness, which can be used more broadly to describe any adhering feature, is the mutual attraction between dissimilar molecules that makes them stick together. The product's degree of adhesivity was represented by its negative adhesiveness value. According to Kaya, Suryani, Santoso, and Rusli (2015), the stickier a product is, the higher its negative value. According to Kaya et al. (2015), adhesiveness is a parameter that is influenced by amylose content and level of starch retrogradation. Although the stickiness value had no significant effect, brownies with the addition of 3% modified suweg flour produced the stickiest brownies compared to other brownies.

The whole modified starch used in the brownies had no gluten content. The use of a large amount of non-gluten flour could make brownies moister, pores tighter, and less tender. The characteristics of wheat flour were comfortable to expand and soft because the powder contained gluten, so the purple sweet potato brownies dough with the addition of modified flour produced less inflated and less soft, optimally and became rather dense. The cohesiveness was also influenced by the viscosity of the mixture, while the viscosity itself was affected by solids, fat, and temperature (Gómez, Ferrero, Calvelo, Añón, & Puppo, 2011; Mendenhall & Hartel, 2016). The addition of modified flour did not affect the viscosity of purple sweet potato brownie dough; this was suspected to be due to the same number of solids in the modified powder. According to Ligarnasari, Anam, and Sanjaya (2018), brownies' moisture, ash, protein, fat, and carbohydrate contents were 24.25%, 1.14%, 7.35%, 36.45%, and 55.35%, respectively, in terms of quality standards.

4.4. The Best Formulation

Table 2 showed that the highest scores were achieved by treatment of a2b3, followed by a1b3 and a3b3 with scores of 39.37, 32.63, and 30.02, respectively. It was indicated in Table 2 that those treatments occurred with the addition of 6 % of each modified flour. The results of the study by Lubis et al. (2021) showed that composite flour (modified breadfruit, purple sweet potato, saga seeds, and mocaf) with a ratio of 35%: 45%: 15%: 5% produced the best quality brownies, whereas in this study, the best brownie formula was obtained with a modified purple sweet potato flour composition of 6%.

5. CONCLUSION

This study showed that purple sweet potato brownies could be made using an autoclave-cooling cycle (ACC) modified tuber flours. The kind and concentration of modified cassava, suweg, and purple sweet potato flour prepared using the Autoclave-Cooling Cycle (ACC) method did not substantially affect the color, aroma, moisture content, hardness, adhesiveness, and cohesiveness of purple sweet potato brownies ($p>0.05$). Purple sweet potato brownies' taste and carbohydrate content differed substantially for ACC ($p<0.05$). Brownies produced with modified sweet potato flour at a 6% concentration (a2b3) received the highest score (39.37), followed by a1b3 and a3b3. The purple sweet potato brownies used in this investigation had 3.53% protein, 1.28% ash, and 16.21% moisture. From an industrial standpoint, the ACC modification technology has high potential for scalability in the starch or flour processing sectors because it relies on very straightforward thermal processing processes (gelatinization, autoclaving, and cooling). However, this study has a number of shortcomings. The results of the sensory evaluation may not be as broadly applicable as they would be due to the small number of inexperienced panelists. Furthermore, the brownies' microbiological safety, shelf life, and storage stability were not assessed. Therefore, larger customer panels, product stability during storage under various packaging conditions, and the techno-economic viability and process optimization of ACC-modified flour production at industrial scale should all be included in future research.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Disclosure of AI Use: The author used QuillBot to paraphrase sentences and used OpenAI's ChatGPT (GPT-4) to edit and refine the wording of the abstract and introduction. All outputs were thoroughly reviewed and verified by the author.

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