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Chemical Characteristics of Bay Tat Traditional Cake at Various Levels of Foxtile Millet (Setaria italica) Flour Substitution

Marietha Kristiani Br. Sinurat
University of Bengkulu
INDONESIA

Sri Wulandari*
University of Bengkulu
INDONESIA

Laili Susanti
University of Bengkulu
INDONESIA

Ulfah Anis
University of Bengkulu
INDONESIA

*** Corresponding author:**
Sri Wulandari, University of Bengkulu, Indonesia. ✉ swulandari@unib.ac.id

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Abstract

Background: Foxtail millet (Setaria italica) has great potential as a substitute for wheat flour due to its favorable nutritional composition and functional properties that support the processing of various food products. The utilization of foxtail millet flour in food products is important to promote food diversification, increase the added value of local commodities, and reduce dependence on imported wheat flour. One potential application of foxtail millet flour is as a partial substitute for wheat flour in a traditional cake known as Bay Tat. However, the effect of the percentage of foxtail millet flour substitution on the chemical quality of *bay tat* cake is not yet known.
Aims: This study aimed to determine the effect of different proportions of wheat flour and millet flour on the chemical quality of traditional Bay Tat cake.
Methods: The study employed a Completely Randomized Design (CRD) with a single factor, namely the combination of wheat flour and foxtail millet flour in five treatments: 100% wheat flour and wheat flour substituted with 20%, 30%, 40%, and 50% foxtail millet flour. The observed parameters included moisture content, carbohydrate content, protein content, and dietary fiber content. The data were analyzed statistically using Analysis of Variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) for parameters showing significant effects.
Result: The results showed that the substitution of wheat flour with foxtail millet flour significantly affected the chemical quality of traditional Bay Tat cake. Increasing the proportion of foxtail millet flour decreased moisture content (23.12%–16.57%) and carbohydrate content (43.24%–37.97%), while protein content increased (7.88%–14.88%) and crude fiber content increased (0.61%–2.56%).
Conclusion: Millet flour has the potential to be used as a substitute for wheat flour in making Bay Tat to increase protein and fiber content and support food diversification based on local commodities.

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INTRODUCTION

Foxtile millet flour has a lot of dietary fiber, protein, and minerals like calcium and iron, which are important for keeping bones and blood healthy (Burbano & Correa, 2021). It is used instead of wheat flour in making gluten-free bread, which helps add more fiber and minerals to the final product (Irondi et al., 2022). This flour is also used to make new products like noodles and fryums because of its special abilities to take in water and oil (Náthia-Neves et al., 2024). Foxtail millet flour has a lot of phenolic compounds and flavonoids, which are antioxidants that may help stop degenerative diseases; it also has antioxidant properties that help the body fight free radicals (Santos et al., 2022). The flour has a good chemical makeup, with protein levels between 6.63% and 11.80%, fat between 1.99% and 3.45%, and carbohydrates between 74.34% and 82.71% (Meza-Nieto et al., 2026).

In Indonesia, foxtail millet is primarily utilized as animal feed; its potential as a food source remains largely unrecognized by the general public (Harish et al., 2024). People are more familiar with wheat flour as the base ingredient for various processed food products, and the demand for wheat flour in Indonesia continues to rise annually (Abedin et al., 2025). Data from Statistics Indonesia (BPS) indicates that in 2023, the country imported 10.59 million tons of wheat (Arora et al., 2023). Consequently, there is a need for alternatives to reduce reliance on wheat flour (Tauseef, 2023). Foxtail millet flour holds promise as an alternative raw material for various processed food products that typically use wheat flour (Chowdhury & Maji, 2024). Demonstrates that substituting up to 45% of the flour with foxtail millet increases fiber and mineral content, although the control bread exhibited the best sensory characteristics (Ilamaran et al., 2021). Fat and carbohydrate levels decreased, whereas total phenolic acids and flavonoid compounds increased in tandem with higher levels of foxtail millet flour (Yang et al., 2021). Millet is considered a beneficial functional food due to its high nutritional value and protein content (Kiritsi, 2026).

In Bengkulu Province, foxtail millet is cultivated across seven regencies: Seluma, South Bengkulu, Kaur, Central Bengkulu, Kepahiang, Rejang Lebong, and North Bengkulu (Pramitha et al., 2023). Local communities utilize the crop as a food source by processing it into various traditional dishes such as porridge, *dodol*, cakes, and *wajik* which are commonly served during harvest thanksgiving ceremonies and other festive gatherings (Candra et al., 2025). The presence and utilization of foxtail millet indicate its potential for further development as a local food source, particularly through the use of millet flour to create innovative food products (Sakshi et al., 2024).

Studies have shown that foxtail millet flour can be used as a replacement in different food items like macaroni, doughnuts, biscuits, *kassipiq* cakes, and sweet bread (Tejaswi et al., 2025). When making sweet bread, mixing wheat flour with foxtail millet flour in a ratio of 8 parts wheat to 2 parts millet was the most liked by the panelists (Kaushik & Singh, 2026). This combination gave the bread better nutrition, with more carbohydrates and dietary fiber than bread made entirely from wheat flour (Harika & Shanmukhi, 2026). These results suggest that foxtail millet flour could be used as a replacement for wheat flour in many types of food items (Kabir et al., 2022).

Bay tat is a traditional pastry from Bengkulu, made from wheat flour and usually served with fillings or toppings like pineapple jam or coconut, as mentioned in (Kurnia & Syarif, 2021). Studies show that replacing wheat flour in bay tat with ingredients like tempeh flour, breadfruit flour, taro flour, and mocaf can help create a new type of pastry using local foods (Alasimi & Ghaisani, 2026).

Since foxtail millet is available in Bengkulu Province, using foxtail millet flour instead of wheat flour to make *bay tat* cakes could be a good way to use local food sources more effectively and decrease the need for wheat flour. So, there's a need for research to look into how replacing some of the flour in bay tat cake with foxtail millet flour affects its chemical properties. Using foxtail millet flour as a replacement for wheat flour in bay tat can offer a new way to make better use of local food sources, increase their value, and reduce reliance on wheat flour. It is not clear what the right amount of foxtail millet flour to use is and how it affects the chemical makeup of bay tat. This study is meant to look at how replacing different amounts of wheat flour with foxtail millet flour affects the chemical makeup of bay tat, including its moisture, ash, protein, fat, carbohydrate, and dietary fiber levels.

METHOD

The study was done at the Agricultural Technology Laboratory, which is part of the Faculty of Agriculture at the University of Bengkulu, and also at the Biology Laboratory in the Faculty of Mathematics and Natural Sciences at the same university. The making of *bay tat* cakes happened at a home-based production facility. This study used a Completely Randomized Design (CRD) with one factor, which was the ratio of wheat flour to foxtail millet flour (T), and it had five different treatment

levels. Each treatment was done three times, which made a total of 15 experimental units. The study's research plan, the way treatments were randomly assigned, and the specific mixtures of ingredients used are all shown in Tables 1, 2, and 3. Foxtail millet flour to wheat flour ratio factor in the production of *bay tat* cake:
T1 (control) = Foxtail millet flour 0%: Wheat flour 100%
T2 = Foxtail millet flour 20%: Wheat flour 80%
T3 = Foxtail millet flour 30%: Wheat flour 70%
T4 = Foxtail millet flour 40%: Wheat flour 60%
T5 = Foxtail millet flour 50%: Wheat flour 50%

Table 1. Research Design

Treatment	Repetition		
	Repetition 1	**Repetition 2**	**Repetition 3**
T1	T_1U_1	T_1U_2	T_1U_3
T2	T_2U_1	T_2U_2	T_2U_3
T3	T_3U_1	T_3U_2	T_3U_3
T4	T_4U_1	T_4U_2	T_4U_3
T5	T_5U_1	T_5U_2	T_5U_3

Table 2. Treatment Randomization Sequence

Treatment	Repetition		
	Repetition 1	**Repetition 2**	**Repetition 3**
T1	T1(5)	T2(2)	T3(7)
T2	T2(6)	T1(14)	T2(10)
T3	T3(3)	T4(4)	T1(1)
T4	T5(12)	T3(11)	T4(8)
T5	T4(13)	T5(9)	T5(15)

Note: 1–15 represent the treatment randomization numbers.

Tabel 1. Formulasi Bahan

Material (g)	Total Material					
	T1	**T2**	**T3**	**T4**	**T5**	**%**
Wheat Flour (g)	617,4	463,05	308,7	154,35	0	30,87%
Millet flour (g)	0	154,35	308,7	463,05	617,4	
Coconut cream (g)	385,8	385,8	385,8	385,8	385,8	19,29%
Sugar (g)	771,6	771,6	771,6	771,6	771,6	38,58%
Margarine (g)	96,4	96,4	96,4	96,4	96,4	4,82%
Egg (g)	69,4	69,4	69,4	69,4	69,4	3,47%
Soda (g)	0,4	0,4	0,4	0,4	0,4	0,02%e

Vanilla (g)	0,2	0,2	0,2	0,2	0,2	0,01%
Salt (g)	1	1	1	1	1	0,05%
Pineapple Jam (g)	57,8	57,8	57,8	57,8	57,8	2,89%
Total (g)	2.000	2.000	2.000	2.000	2.000	100%

The research stages consist of the following:

1. Preparation of equipment and materials: Preparations were made regarding the tools and ingredients to be used during the study. The equipment had to be clean, while the ingredients had to meet standards and be within their expiration dates.
2. Pineapple jam production process: Ten ripe pineapples were prepared, peeled, and cleaned. The pineapples were cut into small pieces and then pureed using a blender. The pineapple puree was cooked with the addition of 1 kg of sugar. Cooking continued until the jam thickened, after which it was removed from the heat and allowed to cool.
3. Bay Tat cake production process: Coconut milk (385.8 ml) and sugar (771.6 g) were boiled and then left to stand overnight. This mixture was then combined with 96.4 g of margarine, 69.4 g of egg, 0.4 g of baking soda, 0.2 g of vanilla, and 1 g of salt. Wheat flour and foxtail millet flour were then gradually added according to the specific ratios (T1, T2, T3, T4, and T5) until the dough became smooth and easy to mold. Portions of 200 g were weighed out and molded. Subsequently, 57.8 g of pineapple jam was added, a dough strip was placed on top, and the surface was brushed with egg yolk. The molded Bay Tat cakes were immediately baked in an oven for approximately 10 minutes at a temperature of 175°C. Finally, the Bay Tat cakes were ready for testing. Analisisis karakteristik kimia terdiri dari:
   a. Moisture content determination is performed using the oven-drying method. First, weigh an empty dish and record its weight (A). Then, weigh approximately 2 g of the pulverized sample, place it in the dish (B), and dry it in an oven at 105°C for 5 hours. Cool the sample in a desiccator and weigh it again (C). This process is repeated until a constant weight is achieved. The moisture content is calculated on a wet basis as follows:
   $\%\ Moisture\ content = \frac{B-C}{B-A} \text{ x } 100$
   Note:
   A = Weight of empty dish (g)
   B = Weight of dish + sample before drying (g)
   C = Weight of dish + sample after drying (g)
   b. Carbohydrate content determination follows SNI 01-2891-1992. A 50 mL sample is pipetted into an Erlenmeyer flask, and 200 mL of 3% HCl is added; the mixture is then heated under reflux on a hotplate at 100°C for 1.5 hours. Afterward, it is cooled, and approximately 0.5 mL of phenolphthalein (PP) indicator and 30% NaOH are added until the solution turns pink; 3% CH_3COOH is then added until the solution becomes clear. The entire mixture is transferred to a 500 mL volumetric flask; a 10 mL aliquot is taken and mixed with 25 mL of Luff-Schoorl reagent, then boiled again under reflux for 12 minutes on a hotplate at 200°C. Subsequently, the mixture is cooled, and 15 mL of 20% KI and 25 mL of H_2SO_4 are added. Titration is then performed using 0.1 N sodium thiosulfate until a light yellow color appears; approximately 0.5 mL of 1% starch indicator is added, and titration continues until the endpoint (milky white) is reached.
   c. Measure about 0.5 grams of the sample and put it into a Kjeldahl flask. Add about 1 gram of selenium mixture and 25 milliliters of concentrated sulfuric acid; swirl the flask and its contents until all of the sample is covered with sulfuric acid. Do digestion in a fume hood

until the solution becomes clear, let it cool down, and then move it into a 100 ml volumetric flask, making sure to rinse it with distilled water. Let the mixture cool down more, then add distilled water up to the desired level, and stir until everything is well combined. Get a receiving flask and put 10 ml of 2% H3BO3 in it. Then add 4 drops of the mixed indicator solution to it. Place 5 milliliters of the sample solution into the distillation flask. Add 10 milliliters of 30% sodium hydroxide and 100 milliliters of distilled water. Heat the mixture until the liquid in the receiving flask is about 50 ml. Wash the end of the condenser with distilled water, and then use the 0.0171 N sulfuric acid solution to measure the amount in the receiving flask.$Protein\ content = \frac{(b-a)x\ Nx\ 0.014x6.25}{sample\ weight} X\ 100\%\%$

Note: a = mL of titrant for the sample
b = mL of titrant for the blank
N = Normality of the NaOH titrant

d. Crude Fiber: The sample is ground until it passes through a 1 mm sieve. A 2 g portion of the sample is weighed, and its fat is extracted using a Soxhlet apparatus. The fat-free sample is transferred to a 600 mL Erlenmeyer flask, and 200 mL of H2SO4 solution is added. The flask is fitted with a reflux condenser (kept closed) and the mixture is boiled for 30 minutes with occasional agitation. Then, 200 mL of NaOH solution is added, and the sample is boiled again under reflux for 30 minutes, agitating occasionally. A filter paper is dried in an oven, cooled in a desiccator, and weighed. The boiled sample is cooled and filtered through the pre-weighed filter paper while being washed with 10% K2SO4. The residue is further washed with boiling distilled water and approximately 15 mL of 95% alcohol. Finally, the filter paper is dried in an oven at 110°C until a constant weight is achieved (1–2 hours), cooled in a desiccator, and weighed

$$Fiber\ content = \frac{W1 - W2}{W}\ x\ 100\%$$

Note: W = Sample weight (g)
W1= Weight of dry filter paper residue (g)
W2 = Weight of dry filter paper (g)

4. The observational data were analyzed using Analysis of Variance (ANOVA) with SPSS 24.0 software at a significance level of α = 5% to determine the effect of the treatments on the quality of *bay tat* cake. Results indicating a significant effect were further analyzed using Duncan's Multiple Range Test (DMRT).

RESULTS

Data on the chemical characteristics of *baytat* cake substituted with pearl millet flour are presented in Table 4.

Table 1. Chemical Characteristics of Bay Tat Cake

No	Treatment	Parameter			
	(% Foxtail Millet Flour: % Wheat Flour)	Moisture Content	Carbohydrate	Protein	Crude fiber
1	0%: 100%	23.13±0.64^{d}	43.24±0.39^{d}	7.88±0.09^{a}	0.61±0.24^{c}
2	20%: 80%	21.62±1.15^{cd}	41.69±0.22^{c}	8.78±0.05^{b}	0.83±0.16^{c}
3	30%: 70%	20.60 ± 0.68^{c}	40.37±0.80^{b}	9.71±0.09^{c}	1.64±0.25^{a}
4	40%: 60%	18.66±0.63^{b}	38.10±0.76^{a}	11.46±0.09^{d}	2.18±0.27^{b}

5	50%: 50%	16.57± 1.68[a]	37.97±0.94[a]	14.88±0.35[e]	2.56±0.15[b]

Note: Values followed by the same letter indicate no significant difference.

In Anova, the results of the analysis showed that the substitution of millet flour had a significant effect on the moisture content of bay tat cake ($p<0.05$). Moisture conten sig. value 0.000, carbohydrate sig.value 0.000, Protein sig. value 0.000 and crude fiber sig.value 0.000.

DISCUSSION

The results showed that the moisture content of the bay tat cake made with millet flour ranged from 16.57% to 23.12%. The highest moisture level was seen in the treatment with 100% wheat flour, which had 23.12% moisture, while the lowest moisture level was found in the treatment that used 50% millet flour and 50% wheat flour, which had 16.57% moisture. As the amount of millet flour used in the recipe goes up, the moisture level in the bay tat cakes tends to go down. This drop is believed to happen because millet flour has very little gluten, only 1.06%, which makes the dough less able to hold onto water while baking. Besides the ingredients used, how much water is in the bread also depends on how it's baked. Factors like the temperature, how long it's baked, how thick the dough is, and what kind of machine is used all play a role in the water content. Which was that sweet bread made with millet flour had less water in it compared to bread made entirely from wheat flour. All the bay tat cake treatments in this study met the required quality standards set by SNI, with their moisture levels staying under the maximum allowed limit of 40%.

Adding foxtail millet flour to wheat flour can increase the water absorption capacity of the dough. Studies show that the addition of millet flour increases water absorption capacity, although it reduces dough stability and development time (Hombing et al., 2026). Substitution of wheat flour with millet flour can reduce the water content in the final product (ADANSE et al., 2021). This condition is in line with the results of this study, where the addition of millet flour will reduce the water content of bay tat cake (sharoba, 2021).

The analysis of variance (ANOVA) results for substituting millet flour in bay tat cakes showed a real effect on the carbohydrate content of the cakes, with a significance level of 0.00, which is less than 0.05. The test for carbohydrate content in bay tat cake made with millet flour showed results ranging from 37.97% to 43.25%. The highest amount of carbohydrates was in the treatment that didn't use any millet flour, and the lowest was in the treatment that had equal parts wheat flour and millet flour. The diagram shows that as more millet flour is added to the cookie recipe, the amount of carbohydrates in the bay tat cookies goes down. This is because millet flour has fewer carbohydrates, about 65%, compared to wheat flour, which has around 74%. It also has more fiber, protein, and minerals. Moreover, when you bake something, some of the carbohydrates can change because of caramelization and the Maillard reaction, which makes the final product have fewer carbs than it started with. These results match the findings from (Satyavathi et al., 2021), who found that adding millet flour to sago cookies lowered the carbohydrate content in the product. Pearl millet flour has less carbohydrates compared to wheat flour. It has 71.80% carbohydrates, while wheat flour has 73.90% (Akeem et al., 2023). This shows that when more millet flour is used in place of other flours, the amount of carbohydrates in bay tat cakes goes down (Prakash et al., 2021).

The analysis of variance (ANOVA) results show that using millet flour in making bay tat cakes actually changes the protein content in the cakes, and this change is statistically significant because the p-value is less than 0.05. The test results for protein content in bay tat cakes made with millet flour substitutes showed values between 7.88% and 14.88%. The least amount of protein was in the treatment that didn't use millet flour, and the most was in the treatment that used half wheat flour and half millet flour. The diagram shows that as more millet flour is added to the recipe, the amount of protein in the bay tat cookies goes up. The rise in protein is because millet flour has more protein (13.01%) than wheat flour (9.61%), so using millet flour instead of wheat flour makes the product have more protein overall. Millet also has important amino acids that add to the product's nutrition. These findings match the study by (Satyavathi et al., 2021), who found that adding millet flour to sago cookies raises the protein level in the final product.

Other studies also indicate that substituting wheat flour with millet flour at a 30% level can increase the protein content and antioxidant activity of biscuits, demonstrating an improvement in nutritional value (Bheemisetti & Gogu, 2025). This is correlated with this study, where increasing the percentage of millet flour substitution increases the protein in bay tat cakes (Balakrishnan et al., 2026). Research (Priya et al., 2026) shows that substituting up to 40% millet flour for wheat flour can produce biscuits with a higher protein content, with values ranging from 11.35% to 12.93%. This suggests that the use of millet flour can increase the nutritional value of the product, especially in terms of protein (Manchanda et al., 2024).

The test results for crude fiber content in bay tat cakes made with millet flour showed values ranging from 0.61% to 2.56%. The least amount of crude fiber was seen in the treatment that didn't include any millet flour, and the most was found in the treatment that had equal parts wheat flour and millet flour. As more millet flour was added to the cookie recipe, the amount of crude fiber in the bay tat cookies went up. The rise was because millet flour has more crude fiber, 7.92%, than wheat flour, which has 2.52%. These results match the findings from (Balakrishnan et al., 2026), who found that adding millet flour to sago cookies raised the product's crude fiber content.

Research (El-Hadidy et al., 2025) indicates that substituting millet flour in food products can significantly increase crude fiber content. For instance, a study on croissants showed that substituting millet flour raised the crude fiber content to 3.14% at a 20% substitution level. In this study, fiber content increased with higher levels of pearl millet flour substitution. The 50%:50% ratio yielded the highest fiber content, at 2.56%.

Implication:

The results of this study show that how much foxtail millet flour is used instead of other flours is a main reason for the chemical makeup and nutrition value of the traditional Bay Tat cake. Using more foxtail millet flour led to lower moisture and carbohydrate levels, but higher protein and fiber content. The mix with 50% foxtail millet flour had the most protein and fiber. In real-world terms, these findings offer a scientific reason for traditional food makers to improve their Bay Tat recipes by using foxtail millet flour instead of regular wheat flour, which can make the food more nutritious. The study also backs up the idea of making a variety of Bay Tat products using local food sources, especially those that have more protein and fiber, and less moisture and sugar. Using foxtail millet flour can help make locally grown millet more valuable, encourage new ways of using traditional foods, and lessen the need for wheat flour.

Research distribution:

This research adds to the existing knowledge by looking at how replacing different amounts of foxtail millet flour affects the chemical makeup of the traditional Bay Tat cake. It adds to what we already know about using foxtail millet as a local food by showing that increasing its amount greatly affects the levels of moisture, carbohydrates, protein, and crude fiber. The study also gives a formula for using foxtail millet flour in Bay Tat, especially when replacing up to half of the original flour, which led to higher levels of protein and crude fiber. These results back the creation of healthier and more varied traditional foods made from local ingredients, and help in lowering the reliance on wheat flour.

Limitations:

This study has several limitations. The analysis focused on certain chemical features like moisture, carbohydrates, protein, and crude fiber, but it didn’t cover other key quality factors such as fat, ash, antioxidant activity, mineral levels, or how the product tastes and looks. Second, the study looked at replacing wheat flour with foxtail millet flour only at levels of 0%, 20%, 30%, 40%, and 50%, which made it hard to find the best level to use beyond what was tested. Third, the study looked at the chemical features of Bay Tat but didn't check other key qualities of the product, like how it feels, how long it stays good, how well people like it, and how well it keeps during storage. So, more studies are needed to find the best way to make the product and to check how it behaves in terms of its physical and chemical properties, how it tastes, its nutrient content, and how well it keeps over time.

Suggestions:

Future research is recommended to evaluate additional quality characteristics of Bay Tat substituted with foxtail millet flour, including fat, ash, mineral composition, antioxidant activity, texture, color, and sensory acceptance, to provide a more comprehensive assessment of product quality. Further studies may also explore a wider range of foxtail millet substitution levels to determine the optimum formulation based on nutritional, physicochemical, and sensory characteristics. In addition, storage stability and shelf-life studies are suggested to evaluate the quality changes of Bay Tat during storage. Consumer preference and economic feasibility analyses are also recommended to assess the potential for developing foxtail millet-based Bay Tat as an innovative and commercially competitive traditional food product.

CONCLUSION

Substitution of wheat flour with mi llet flour has a significant effect on the parameters of moisture, carbohydrate, protein and crude fiber content. Substituting wheat flour with millet flour up to 50% succeeded in increasing the nutritional value of bay tat cake significantly, especially in the aspect of increasing protein and crude fiber, as well as reducing the water and carbohydrate content of the product.

AUTHOR CONTRIBUTION STATEMENT

MK br S conducted the experiments and collected the data. SW interpreted the results, and contributed to the drafting and revision of the manuscript. LS served as the proofreader, ensuring clarity, consistency, and linguistic accuracy throughout the final manuscript. UA conceived and designed the study, and final manuscript.

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