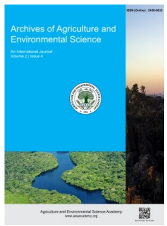
Archives of Agriculture and Environmental Science 10(4): 671-676 (2025)
https://doi.org/10.26832/24566632.2025.1004016

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



ORIGINAL RESEARCH ARTICLE

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# Preparation of muffin incorporated with sweet potato paste and its quality evaluation

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**ARTICLE HISTORY**

Received: 09 October 2025
Revised received: 12 December 2025
Accepted: 18 December 2025

**Keywords**

Fiber
Low gluten
Muffins
Sensory evaluation
Sweet potato

**ABSTRACT**

This study examines the development of low-gluten sweet potato muffins, focusing on process optimization, sensory evaluation, and proximate composition analysis. Raw materials were selected based on freshness, quality and processed through sorting, grading, boiling, mashing, baking, and cooling steps. Five formulations (A- 0%, B-30%, C-40%, D-50% and E-60% of sweet potato paste) were prepared based on survey data, from which the best formulated one was selected through 9-point hedonic scale. The study examined how varying levels of steam-cooked sweet potato paste influenced the muffins' chemical and nutritional properties. Sample D was identified as the best formulation based on sensory tests, showing superior qualities in color, scent, taste, texture, and overall acceptability. The moisture, protein, fat, ash, crude fiber and carbohydrate content of best formulated product was 29.7, 5.38, 17.23, 1.62, 2.85 and 43.19%, respectively. Also, beta carotene content and calcium content were 4.49 mg/100 g and 11.64 mg/100 g, respectively. The nutritional profile and sensory quality of the low-gluten muffins were significantly ($p<0.05$) improved by adding 50% sweet potato paste, while maintaining a reasonable price. According to the study, sweet potatoes can be used as a functional ingredient to create nutrient-rich baked goods that will appeal to consumers and have potential commercial value.



**Citation of this article:** Khatiwada, K., Bhattarai, M., Risal, A., Bhatta, R. C., & Kharel, B. (2025). Preparation of muffin incorporated with sweet potato paste and its quality evaluation. *Archives of Agriculture and Environmental Science*, *10*(4), 671-676, https://dx.doi.org/10.26832/24566632.2025.1004016

## INTRODUCTION

The word "muffin" is believed to have originated from the French word moufflet, which means "soft bread" are one of the beloved baked good made from wheat flour. The four main elements that largely dictate the muffin's composition, appearance, and taste: egg, flour, sugar, and oil. Additives including emulsifiers, baking powders, and milk are also frequently utilized. These components are blended in a method that encourages aeration, which adds bubbles to the mixture, to form a muffin or cake batter system. The final volume and crumb quality of a cake or muffin are crucial markers of its quality (Öztürk & Mutlu, 2018). They are enjoyed by people of all ages and are often seen in bakeries, coffee shops, and even homemade kitchen recipes. The complex combination of ingredients that makes up muffin batter includes a high percentage of sugar as well as varying amounts of fat, flour, egg, emulsifier, milk powder, baking powder, and preservative (Shevkani *et al*., 2015). Emulsifiers helps to incorporate and divide air into the liquid phase during the baking of cakes and muffins, promoting a uniform dispersion of fat with retained air cells and increasing the number of sites available for gas expansion, which gives the finished product more volume and a softer texture (Manisha *et al*., 2012). Popular flavors include banana nut, chocolate chip, and blueberry, while British muffins, in contrast, retain their traditional round shape and are often served toasted with butter or as a side to savory dishes such as eggs Benedict (Chan, 2014). Fruits, nuts, spices, chocolate, and vegetables are just a few examples of the ingredients that can be used to create the flavors (Srivastava *et al*., 2012). Muffins made with higher protein flours are chewier, while those made with lower protein flours have a more delicate crumb (Tanno & Willcox, 2016).

The sweet potato (*Ipomoea batatas*) is a dicotyledonous plant belonging to the Convolvulaceae family, which also includes bindweed and morning glory. It is believed to have originated and been domesticated in Central or South America. Archaeological evidence suggests that domesticated sweet potatoes appeared in Central America at least 5,000 years ago (Zhang *et al.*, 2000). Its large, starchy, sweet-tasting tuberous roots are eaten as a root vegetable. This vegetable is delicious, highly versatile, and has a tremendous nutritional value. Additionally, it has anti-inflammatory, anti-cancer, and anti-diabetic qualities, making it a very beneficial medicinal herb (Mohanraj & Sivasankar, 2014). It is marketed as a suitable alternative diet and an excellent source of carbohydrates as part of the effort to combat vitamin A deficiency in children and pregnant women. Due to their distinct nutritional and functional characteristics, sweet potatoes have recently attracted the attention of researchers. Sweet potatoes have also been used to produce sweet potato steamed breads, baked breads, noodles, pancakes also snack foods, such as sweet potato chips, roast sweet potatoes, biscuits, dried slices, cakes, doughnuts, and extruded snacks (Mu & Singh, 2019). Sweet potatoes with yellow and orange flesh include a variety of phenolic acids (such as hydroxycinnamic acids) and have comparatively high levels of carotenoids (such as -carotene). Sweet potatoes with purple flesh have a lot of acylated anthocyanins and other phenolics have anti-inflammatory and antioxidant properties (Grace *et al.*, 2014). Sweet potato is used in baking as a dough conditioner and as an alternative flour in the production of gluten-free products. Sweet potatoes can be incorporated into many different cake recipes, including classic cakes, muffins, cupcakes, and even cheesecakes. Their mild flavor blends well with various flavors and substances (Selvakumaran *et al.*, 2019). In recent years, nutrient-dense ingredients have gained popularity as a way to improve baked foods nutritional profile without sacrificing flavor or texture. Sweet potatoes are one such versatile root vegetable, they are also a great source of vitamins, minerals, and nutritional fiber. By adding antioxidants like beta-carotene, potassium, and vitamin C, sweet potatoes enhance the nutritional content of muffins and provide natural sweetness, moisture, and a soft texture. This creative method gives classic muffin recipes a touch that enhances their flavor and nutritional value while also appealing to consumers who are health-conscious (Truong *et al.*, 2007). Wheat-based muffins are a popular breakfast and snack option, but they are often made with refined flour, which lacks certain essential nutrients and fiber. Thus, there is a need to address this limitation and improve the nutritional profile and texture of wheat- base muffins. The problem at hand is to develop a wheat-based muffin recipe that enhances the nutritional value while maintaining an appealing texture. It is important to address the challenge of maintaining a desirable muffin texture when incorporating wheat flour and sweet potato paste that can alter the dough's consistency. The aim of the study was to create a product that offers improved nutritional value without compromising the sensory experience, ultimately leading to a more sustainable and appealing baked good option.

## MATERIALS AND METHODS

### Raw materials

Refined wheat flour (Gyan Fortified Maida), fresh orange-fleshed sweet potatoes, commercial sugar, eggs, salt, baking powder, butter (Amul), and pasteurized milk (DDC) were collected from various commercial outlets and local markets. All raw materials were selected based on freshness and suitability for muffin preparation. The analyses were conducted using standard laboratory equipment, including a hot air oven, analytical balance, desiccator, muffle furnace, Soxhlet extraction unit, heating mantle, vacuum filtration assembly, titration and distillation units, dehydrator, water bath, blender, baking oven, separation funnel, and Kjeldahl apparatus. All instruments were cleaned, calibrated, and operated following standard laboratory procedures.

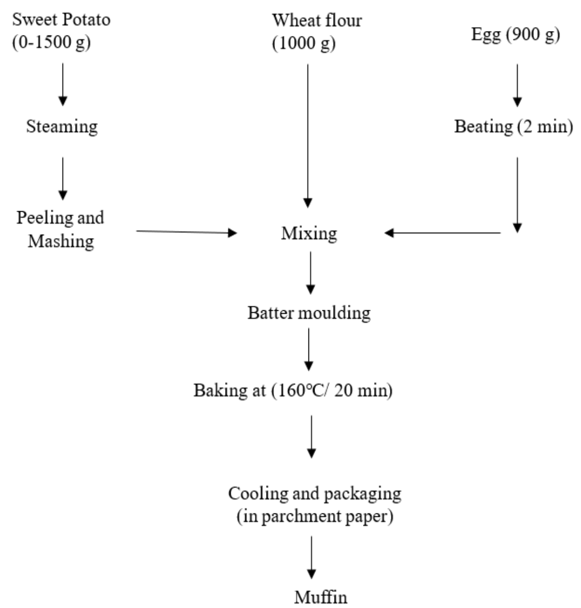
### Experimental design

### Selection of site

The study was conducted from July 24 to August, 2024, in the Food Science Laboratory in Kathmandu. Five muffin formulations were prepared by substituting sweet potato paste for wheat flour at 0% (A), 30% (B), 40% (C), 50% (D), and 60% (E), with the 0% formulation serving as the control (Table 1).

### Preparation of sweet potato paste and Muffins

Sweet potatoes were washed, steamed, peeled, and blended into a uniform paste. Muffins were prepared using the standard muffin method, in which dry (wheat flour, sugar, baking powder, salt) and wet (butter, eggs, milk, sweet potato paste) ingredients were mixed separately and then combined to form a homogeneous batter. The batter was deposited into molds and baked at 160°C for 20 minutes, followed by cooling at room temperature before packaging (Figure 1).



A mixed muffin batter was made by mixing the dry and wet ingredients and then baked.

**Figure 1.** *Preparation of sweet potato paste incorporated muffin.*

### Chemical analysis of muffins

Proximate composition (moisture, crude fat, crude protein, crude fiber, ash, and carbohydrate) was determined using standard methods described by (Rangana, 2011). Moisture was measured by the hot-air oven method, fat by Soxhlet extraction, protein by the macro-Kjeldahl method, fiber by acid–alkali digestion, and ash by dry ashing. Beta-carotene content was determined as per Srivastava *et al.* (2012) using acetone extraction and spectrophotometric measurement at 452 nm. Calcium content was measured by EDTA titration as outlined (Rangana, 2011). Carbohydrate content was calculated by using the formula. Carbohydrate (%) = 100 – (moisture + protein + fat + ash + crude fiber)

### Physical parameter analysis

Bulk density was calculated as the ratio of muffin mass to volume (Eq. 1). Baking loss (%) was expressed as the percentage reduction in weight after baking, based on pre- and post-baking weights (Eq. 2).

$$\text{Bulk density} = \frac{\text{Mass of muffin (g)}}{\text{Volume of muffin (cm}^3\text{)}} \qquad (1)$$

$$\text{Baking loss (\%)} = \frac{\text{Wi} - \text{Wf}}{\text{Wi}} \times 100 \qquad (2)$$

Where,

$$\text{Wi} = \text{Pre} - \text{bake weight and Wf} = \text{Post} - \text{bake weight after cooling}$$

### Sensory evaluation

Sensory evaluation was carried out using a 9-point hedonic scoring system (1 = dislike extremely, 9 = like extremely) to assess appearance, color, taste, flavor, mouthfeel, and overall acceptability as described by (Rangana, 2011). A semi-trained panel of 15 individuals (faculty and students) assessed coded samples in a controlled laboratory environment. Each panelist was given five coded samples and an individual score sheet.

### Data analysis

Data from sensory analysis was recorded and illustrated using Microsoft Excel 2013. The data from proximate analysis was subjected to ANOVA and t-test. The data was statistically examined in triplicate, and the analysis of variance was performed using the Statistical Analysis System IBM SPSS Statistics 20.

## RESULTS AND DISCUSSION

### Proximate composition of wheat

The proximate composition of wheat flour was analyzed, and the findings are presented in Table 2. The moisture content of wheat flour was found to be 14.32%. The moisture content of wheat flour was in the higher range than observed by USDA Fooddata Central (12-13.5%). The protein content, fat, ash, fiber and carbohydrate of wheat flour were found to be 10.99, 1.08, 0.40, 0.74, and 73.47 g/100 g, respectively. Varieties, climatic conditions, soil type, maturity, fertility, processing methods, and other factors may contribute to differences in proximate composition.

### Proximate composition of sweet potato

The proximate composition of fresh sweet potatoes was analyzed, and the findings are presented in Table 3. The moisture content of sweet potato was determined by hot air oven method and found to be 71.32% which is slightly greater than that of sweet potato as given by Rodrigues *et al.* (2016). Other components like protein was determined to be 1.65%, fat was found to be in higher range i.e., 1.59% as observed by Rodrigues *et al.* (2016). Crude fiber and total ash was found to be 2.33% and 1.97% respectively which was similar to the result found by Rodrigues *et al.* (2016). Earlier research on Sweet Potato Shrikhand also demonstrated enhanced nutritional quality due to sweet potato addition, supporting the nutrient improvements observed in the optimized muffin sample (Gonjari *et al.*, 2025).

**Table 1.** Recipe for muffins.

| Ingredients | Formulations (g) | | | | |
|---|---|---|---|---|---|
| | A (0%) | B (30%) | C (40%) | D (50%) | E (60%) |
| Fine wheat flour | 1000 | 1000 | 1000 | 1000 | 1000 |
| Sweet potato | 0 | 750 | 1000 | 1250 | 1500 |
| Whole eggs | 900 | 900 | 900 | 900 | 900 |
| Butter | 500 | 500 | 500 | 500 | 500 |
| Sugar | 500 | 500 | 500 | 500 | 500 |
| Salt | 10 | 10 | 10 | 10 | 10 |
| Milk | 100 | 100 | 100 | 100 | 100 |
| Baking powder | 40 | 40 | 40 | 40 | 40 |

**Table 2.** Proximate composition of wheat flour (Gyan fortified maida).

| Constituents | Amounts (g/100g) | Reference value (label) (g/100g) |
|---|---|---|
| Moisture | 14.32 ± 0.21 | - |
| Carbohydrate | 73.47 ± 0.64 | 75.2 |
| Crude Protein | 10.99 ± 0.82 | 9.7 |
| Crude fat | 1.08 ± 0.16 | 1 |
| Crude fiber | 0.74 ± 0.01 | - |
| Total ash | 0.40 ± 0.03 | - |

Values are the means of triplicates analyses. ± indicates the standard deviation from mean.

**Table 3.** Proximate composition of sweet potato.

| Constituents | Amounts (g/100 g) |
|---|---|
| Moisture | 71.32 ± 0.83 |
| Carbohydrate | 21.02 ± 0.23 |
| Crude protein | 1.65 ± 0.22 |
| Crude fat | 1.59 ± 0.45 |
| Crude fiber | 2.33 ± 0.52 |
| Ash | 1.97 ± 0.87 |

Values are the means of triplicates analyses. ± indicates the standard deviation from mean.

**Table 4.** Losses during baking of muffin.

| Sample | Baking loss (%) |
|---|---|
| A | 3.7 |
| B | 4 |
| C | 5.2 |
| D | 6.4 |
| E | 6.8 |

A: Control cake; B: 30% paste incorporated cake; C: 40% paste incorporated cake; D: 50% paste incorporated cake; E: 60% paste incorporated cake.

**Table 5.** Bulk density of muffins at different level of sweet potato paste.

| Sample | Weight (g) | Volume (cc) | Bulk density (g/cc) (g/cm3) |
|---|---|---|---|
| A | 2410 | 4536 | 0.53 |
| B | 2400 | 4805 | 0.5 |
| C | 2370 | 5032 | 0.47 |
| D | 2340 | 5221 | 0.44 |
| E | 2310 | 5500 | 0.42 |

A: Control cake; B: 30% paste incorporated cake; C: 40% paste incorporated cake; D: 50% paste incorporated cake; E: 60% paste incorporated cake.

## Physical analysis of muffins

### Baking loss (%)

The term "baking loss" describes how the weight of baked goods decreases after baking in comparison to the weight of the batter or dough before baking. It mostly arises from the loss of moisture and volatiles, like alcohol or specific gases, during the baking process and is typically reported as a percentage. Baking loss showed a loss in weight during baking, which was calculated based on batter weight and final product weight. Different proportion of sweet potato paste was used for the preparation of muffin and baking loss is shown in Table 4. The highest baking loss of 6.8% is observed in sample E which is the sample with 60% of sweet potato paste. Then the baking loss is observed to fall to 6.4 in sample B which is 50 % incorporation of sweet potato paste. Consistent trend of decreasing baking loss can be observed in other samples where sweet potato is decreased. The least baking loss of 3.7% can be seen in sample A which is control sample and has 0% of sweet potato paste.

### Bulk density of muffins

Bulk density of muffins at different levels of sweet potato paste are presented in Table 5. The volume of a cake is the most important physical feature to consider while evaluating it. It is a numerical measurement that is closely related to the qualities of handling dough, texture, freshness, and technological flexibility (Khan *et al*., 2017). It can be seen that the control cake has the smallest volume and that muffin volume grows as the amount of sweet potato paste in the recipe increases. The bulk density of the muffins is also observed to be increasing with the increasing incorporation of sweet potato paste.

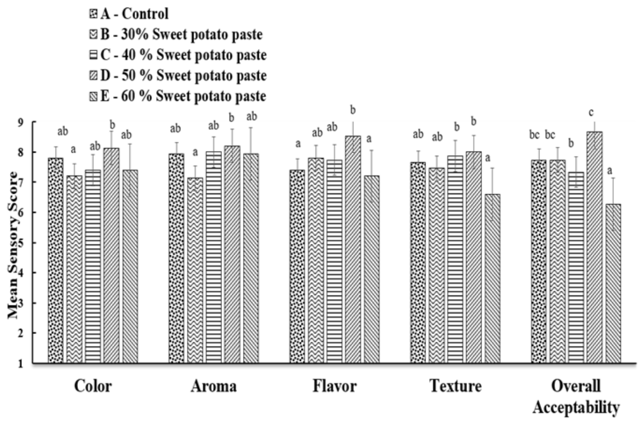



**Figure 2.** *Sensory evaluation of prepared muffin incorporated with different proportions of sweet potato paste.*

## Sensory evaluation of muffins

### Color

The mean sensory ratings for color were 7.8, 7.2, 7.4, 8.1, and 7.4 for formulations A, B, C, D, and E, respectively (Figure 2). Color acceptability was best in Formulation D and lowest in Formulations B and E. At the 5% significance level, formulations A, D, B, and E were not significantly different, whereas A, D, and C showed significant differences. Overall, significant differences existed between the groups. The Maillard reaction, in which amino acids react with sugars to produce brown-colored compounds, may be the cause of the darker color of muffins when they contain sweet potato paste. Higher protein content of sweet potatoes probably sped up this process, making the muffins darker than the control sample. Similar trends have been observed in other food products enhanced with sweet potato paste, where the presence of color-active substances

**Table 6.** Comparison of proximate composition of control and best product.

| Parameters | Product A (Control) | Product D (Best Product) |
|---|---|---|
| Moisture | 25.52 ± 2.06 | 29.71 ± 1.75 |
| Carbohydrate | 45.37 ± 1.29 | 43.19 ± 1.92 |
| Crude protein | 6.06 ± 0.79 | 5.38 ± 0.35 |
| Crude fat | 19.66 ± 0.50 | 17.23 ± 0.91 |
| Ash | 2.08 ± 0.28 | 1.62 ± 0.30 |
| Crude fiber | 1.29 ± 0.30 | 2.85 ± 0.21 |
| Beta-carotene | 0.11 ± 0.01 | 4.49 ± 0.48 |
| Calcium content | 8.00 ± 0.68 | 11.64 ± 1.74 |

Values are the means of triplicate analyses. ± Indicates the standard deviation from mean.

such anthocyanins and other phytochemicals amplified the product's intrinsic pigment and produced richer color tones (Julianti *et al*., 2025). This explains why muffin recipes with higher paste levels have a deeper hue.

### Aroma

In terms of aroma, a similar result was observed. Sample D had the highest mean sensory score for aroma (8.2), whereas sample B had the lowest (7.1). At the 5% level of significance, statistical analysis revealed that the formulation's impact on the product's aroma was considerably different ($p<0.05$) (Figure 2). Additionally, it demonstrates that there is a significant difference between A and B, while there is no significant difference between C, D, and E.

### Flavor

The mean sensory scores for flavor were 7.4, 7.8, 7.7, 8.5, and 7.2 for muffin formulations A, B, C, D, and E, respectively (Figure 2). Products A and E had the lowest amount of acceptance based on flavor, whereas product D has the highest level. At the 5% level of significance, statistical analysis revealed that the product's flavor was considerably affected by the formulation ($p<0.05$).

### Texture

With a mean sensory score of 8, sample D had the greatest score, while sample E had the lowest (6.6). Samples A, B, and C scored 7.6, 7.4, and 7.8 on the sensory scale. Sweet potatoes helped incorporate air into the batter to produce the required final volume and spongy texture. According to statistical analysis, at the 5% level of significance, the impact of formulation on the product's texture was significantly different ($p<0.05$). Additionally, it demonstrates that while A and D differ significantly, B, C, and E do not differ significantly.

### Overall acceptability

The mean sensory scores for the muffin formulations A, B, C, D, and E were 7.7, 7.7, 7.3, 8.6, and 6.2, respectively, in terms of overall acceptability. Products B, C, and E have the lowest level of acceptability, whereas D has the highest level of acceptability overall. At the 5% level of significance, statistical analysis revealed that the impact of formulation on the product's overall acceptance was significantly different ($p<0.05$). Additionally, it demonstrates that while there is a significant difference between A and D, but no significant difference between B, C, and E. High consumer acceptability of alternative flour muffins has also been reported in taro banana formulations (Ervina & Imannuel, 2025).

### Nutritional composition of control and best product

The sample D muffin, which had 50% sweet potato paste, was found to be the best product based on statistical sensory analysis. Table 6 displays the approximate composition of sample D and the control muffin (made entirely of wheat flour). Products A and D had moisture contents of 25.52% and 29.71%, respectively. The moisture level of the control muffin and the best product (D) did not differ significantly. According to Manisha *et al*. (2012), the control muffin's protein, fat, ash, fiber, and carbohydrate contents were 6.06%, 19.66%, 2.08%, 1.29%, and 45.37%, respectively. The best-formulated muffin, on the other hand, had 5.38% protein, 17.23% fat, 1.62% ash, 2.85% fiber, and 43.19% carbohydrates. The fat and fiber contents of the best-formulated and control muffins differed significantly. Compared to the control, the best-formulated muffin (D) had more fiber but less fat. However, there was no discernible difference in the two products' protein and carbohydrate compositions. Additionally, the beta-carotene and calcium contents were higher in the best-formulated product, which can be attributed to the incorporation of sweet potato paste.

## Conclusion

Based on sensory analysis, this study prepared muffins with sweet potato paste and determined that the 50% substitution level (Product D) was the most palatable formulation. In comparison to the control, the optimized product exhibited significantly higher β-carotene (4.49 mg/100 g dry matter) and enhanced calcium content (11.64 mg/100 g) while still being reasonably priced. The incorporation of orange-fleshed sweet potato paste significantly enhanced the nutritional value of the muffin without affecting overall acceptability. These results imply that sweet potato paste, a naturally occurring, locally accessible ingredient, can be practically used in baked goods to increase their nutritional content. However, the study was constrained by the lack of detailed mineral analysis, packaging evaluation, and shelf-life determination. Future studies should examine additional minerals, check microbiological stability, investigate appropriate packing materials, and measure texture and color using instrumental techniques.

## DECLARATIONS

**Author contributions statement**: Conceptualization: K.K.; Methodology: K.K., M.B. and A.R.; software and validation: K.K.,M.B.,A.R..,B.K.; Formal analysis: K.K.,M.B.,A.R.; Investigation: A.R.,B.K.; Resources: M.B.,B.K.; Data curation: K.K.,M.B.,A.R.; Writing original draft preparation: K.K.,A.R.,R.C.B.; writing- review and editing: K.K., A.R., R.C.B.; Visualization: M.B., A.R.; Supervision: A.R and R.C.B.; Project administration: K.K.; Funding acquisition: K.K and A.R.; All authors have read and agreed to the published version of the manuscript.

**Conflicts of interest:** The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

**Ethics approval:** This study did not involve any animal or human participant and thus ethical approval was not applicable.

**Consent for publication:** All co-authors gave their consent to publish this paper in AAES.

**Data availability:** The data that support the findings of this study are available on request from the corresponding author.

**Supplementary data:** No supplementary data is available for the paper.

**Funding statement:** No external funding is received for this study.

**Additional information:** No additional information is available for this paper.



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