

Development of Soy Milk Vegan Choco-Chip Muffins

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Abstract

This study explores the development of soy milk-based choco chip muffins, aimed at creating a nutritionally superior, plant-based bakery product for health-conscious consumers. Special grain flour (Fenugreek and oats) was used to enrich dietary fiber, enhance nutritional value, and contribute to a balanced texture. Dairy-free soy milk was utilized to enhance protein content and moisture retention, while Peanut butter or flaxseed paste was used as egg replacers. Dates paste was used as a natural sweetener, reducing reliance on refined sugars. Vegetable oil (combination of soybean, rice bran, and flaxseed oils) was employed to improve lipid stability and mouth feel.

Sensory evaluation was conducted using a semi-trained panel to assess attributes such as appearance, texture, flavor, and overall acceptability. Microbial safety was assessed through total plate count, coliform count, yeast and mold enumeration, and also detection of *Staphylococcus aureus*, *Salmonella spp.*, and *Escherichia coli*. The muffins underwent comprehensive nutritional analysis, such as moisture, protein, fat, ash, dietary fiber, carbohydrate levels and pH. A shelf-life study was performed under ambient conditions and refrigerated conditions. The findings supported the feasibility of incorporating functional ingredients into vegan muffins while maintaining safety, palatability, and nutritional integrity.

Keywords: vegan muffins, soy milk, fenugreek and oat flour, date paste, peanut butter, flax seeds paste, vegetable oil, choco-chips, sensory evaluation, microbial safety, nutritional analysis, shelf-life study.

1. INTRODUCTION

Muffins are popular single-serving baked goods known for their soft texture and sweet flavor (Baixauli et al., 2008). Conventional muffins typically contain animal-derived ingredients and refined flour, which may not suit vegan or health-conscious consumers (Man et al., 2014). With rising awareness of ethical and nutritional concerns, the bakery industry is shifting toward plant-based, allergen-free, and functional products (Shih, 2020; Cross, 2007). Vegan muffins, in particular, offer indulgence and nutrition through clean-label formulations (Yadav et al., 2022). Recent innovations focus on replacing the structural roles of eggs and dairy using functional ingredients (Shukla & Verma, 2024). Soymilk, a protein-rich dairy alternative, enhances moisture retention and microbial stability (Vishali & Agarwal, 2023). Peanut butter or flaxseed paste serve as emulsifiers and egg replacers, supporting texture and nutritional density (Sharma & kaur, 2024; Talwar & Baansal, 2025). Fenugreek and oat flour replacing maida, improves fiber, mineral, and antioxidant content (Negu & Raol, 2020; Jain & Mehta., 2024). Dates paste serves as a natural

sweetener replacing white sugar, and aligns with low glycemic goals (Ahemed and Thomas, 2019). Vegetable oils like soybean, rice bran, and flaxseed oil improve crumb softness and shelf life (Yadav & Singh, 2022). choco chips contribute sensory appeal (Grasso et al., 2020).

This study deals with development of a vegan choco chip muffins using soymilk, fenugreek and oats flour, dates, peanut butter / flax seed paste, vegetable oil mixture and choco chips. Multiple trials were conducted to optimize taste, texture, aroma, and appearance. The selected formulation was evaluated for nutritional composition, microbial safety, and shelf-life stability.

2. MATERIALS AND METHODS

2.1 Preparation of vegan muffins

Five formulation trials were conducted to optimize the composition and baking method for the development of vegan chocolate chip muffins. The ingredient compositions for each formulation trial and ingredients of conventional muffins are given in Table 2. 1.

All utensils and mixing bowls were cleaned and ingredients were brought to room temperature in each trial. Wet ingredients such as soymilk and apple cider vinegar were initially mixed and left for 10 minutes for curdling, creating vegan milk. Vegetable oil, peanut butter or flaxseed paste, dates paste, and vanilla extract were added and mixed with a hand mixer to create a smooth emulsion in another bowl. Prepared vegan milk was added to this emulsion and wet ingredient mixture was prepared. Dry ingredients such as fenugreek -oats flour, cocoa powder, baking powder, baking soda, and salt were mixed evenly in another bowl. The wet ingredient mixture was then slowly added into the dry ingredients mixture to prevent clump formation and vegan muffin batter was prepared. The batter was poured into muffin moulds and choco chips were topped.

Two procedures were used for baking of vegan muffins, which are the traditional sand-plate method for formulation trials 1 to 3 and the electric oven method for formulation trial 4 and 5.

Table 2.1: Composition of ingredients in Vegan Muffins for formulation trials 1-5 and conventional muffins

S.No.	Ingredient	Source	Quantity of Ingredient					General Muffin Ingredient
			Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	
1	Soya milk	Sofit	120 ml	120 ml	120 ml	120 ml	120 ml	Dairy milk
2	Special grainFlour	Aashirvaad	120 g	120 g	80 g	120 g	120 g	Refined wheat flour(maida)
3	Dates paste	Arabian Dates	120 g	240 g	240 g	240 g	240 g	White sugar
4	Choco chips	Araku Coffee Estate	90 g	22 g	22 g	45 g	22 g	Raisins or nuts

5	Peanut butter (Trial1&2) or flaxseed (Trial3-5)	Kissan	32 g	64 g	64 g	32 g	16 g	Eggs
6	Vegetable oil	Fortune	120 ml	120 ml	120 ml	60 ml	60 ml	Butter
7	Cocoa powder	Hershey's	7.5 g	3.75 g	3.75 g	3.75 g	3.75 g	Fruit puree or vanilla essence
8	Apple cider vinegar	Disano	5 ml	2.5 ml	2.5 ml	2.5 ml	2.5 ml	Normal vinegar
9	Vanilla extract	Rajassorted	2.5 ml	1.25 ml	1.25 ml	2.5 ml	2.5 ml	Vanilla essence
10	Baking powder	Weikfield	4 g	4 g	4 g	4 g	4 g	Baking powder
11	Baking soda	Premia	1 g	1 g	1 g	1 g	1 g	Baking soda
12	Salt	Tata Salt	1.5 g	1.5 g	1.5 g	1.5 g	1.5 g	Salt

2.2 Sensory Evaluation of vegan muffins for formulation trials 1 to 5

Five formulation trials of vegan muffins were evaluated to determine the most favourable formulation trial vegan product in terms of nutrition, sensory appeal and consumer preference. Formulation trials of 1 to 3 were evaluated by informal method for 4 attributes such as appearance, texture, flavour and aroma. The formulation trials 4 and 5 were evaluated by a five-member semi-trained panel using a 5-point hedonic scale rating for attributes such as appearance, texture, flavour, odour, moistness, sweetness, after taste, crust texture, filling distribution, and overall acceptability.

2.3 Microbial Analysis of vegan muffins for formulation trial 5

Microbial analysis of the Vegan muffins for the formulation Trial 5 was assessed using standard plate count methods under aseptic conditions. Total Plate Count (TPC) was performed on Plate Count Agar at 37 °C for 24–48 hours, while yeast and mold counts were detected using Rose Bengal Chloramphenicol Agar at 25 °C for 3–5 days. Coliforms were detected using Violet Red Bile Agar, and pathogen screening involved Mannitol Salt Agar for *Staphylococcus aureus* and Salmonella-Shigella Agar for *Salmonella* spp. All media and glassware were sterilized at 121 °C for 15 minutes (15 psi) before use.

For sample preparation, 1g of the food sample was weighed and transferred into a sterile dilution tube containing 9 mL of distilled water. The mixture was thoroughly blended using a cyclo mixer. From this stock solution, 1mL was transferred into a second sterile tube containing 9mL of distilled water, mixed

again, and labeled as 10^{-1} . A second dilution was prepared by transferring 1mL from the 10^{-1} tube into another 9mL of distilled water, mixed thoroughly, and labeled as 10^{-2} . All dilutions were mixed using the cyclo mixer to ensure uniformity.

Two sterile Petri plates were prepared: one served as a control plate and the other as the test plate. From the 10^{-2} dilution, 1mL was transferred to the test plate. Approximately 15–20mL of molten agar was added to both plates, and the contents were gently rotated to ensure even distribution. The plates were incubated in an inverted position at 37 °C for 24–48 hours and observed for growth of colonies. The colony Count is calculated as follows: $(CFU/g) = \{\text{Number of colonies}\} * \{\text{Dilution factor}\} / \{\text{Volume plated (mL)}\}$

2.4 Nutritional Analysis of vegan muffins for formulation trial 5

Nutritional analysis of the Vegan Muffins for formulation Trial 5 was performed using standard analytical procedures to determine key nutritional parameters. Moisture content was measured by the oven dry method, protein content by the Kjeldahl method, and fat content by petroleum benzene extraction. Ash was detected using the incineration method, while crude fiber was measured by gravimetric analysis. Carbohydrate content was calculated by difference method, and pH was measured using a digital pH meter (Md Noh et al., 2020).

2.5 Shelf-life study of vegan muffins for formulation trial 5

Shelf-life evaluation was conducted over a 7-day period under controlled ambient conditions (25 ± 2 °C, 60–65% RH) and refrigerated conditions. Muffins were stored in airtight containers and assessed for freshness, and visible spoilage.

3. RESULTS AND DISCUSSION

3.1 Preparation of Vegan Muffins for Formulation Trials of 1 to 5

Soy Milk Vegan Choco-Chip Muffins were successfully prepared using both traditional sand plate method and electric oven method in all formulation trials of 1 to 5 (Fig 3. 1).

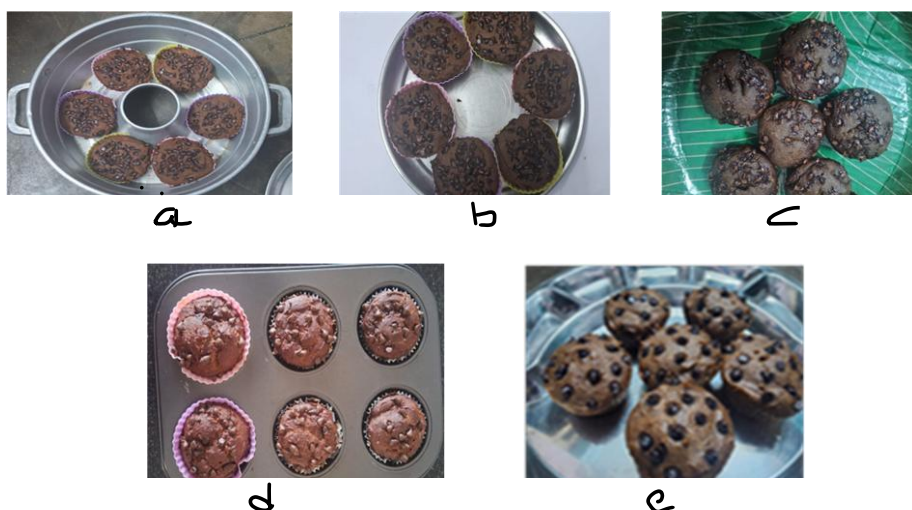


Figure 3.1: Baked vegan Muffins of Formulation Trials 1(a), 2(b), 3(c), 4(d) and 5 (e)

3.2 Sensory Analysis of vegan for formulation trials 1 to 5

Trial 1 used a basic recipe with peanut butter as the main binder, along with moderate cocoa powder and 120 g dates paste. Informal feedback from three family members showed that the muffins had a good appearance and aroma, indicating a pleasant look and smell. However, flavour was rated “Average” due to low sweetness and slight bitterness, likely from the more cocoa powder and limited dates paste. Texture received mixed responses, suggesting acceptable softness but lacking smoothness. The results highlighting the role of fat-based binders in texture and flavour. (Kemp, 2008) (Table 3.1)

Trial 2 modified the initial recipe by doubling peanut butter (32 g to 64 g) and increasing dates paste (120 g to 240 g) to enhance texture and sweetness. Cocoa powder and vanilla extract were slightly reduced. Sensory feedback showed consistent “Good” ratings for appearance, aroma, and flavour, indicating improved sweetness and balanced bitterness. Texture received mixed ratings—one “Good” and two “Average”—suggesting improved softness but persistent density due to unchanged flour and oil. These results align with Drewnowski (1997), who noted fat-based binders improve mouthfeel but not crumb uniformity. Trial 2 guided the switch to flaxseed paste in Trial 3 (Table 3.1).

Trial 3 replaced peanut butter with 64 g flaxseed paste to improve nutrition and achieve a lighter texture. Dates paste remained high (240 g) for sweetness, while flour was reduced from 120 g to 80 g to soften the crumb. Cocoa powder, oil, and vanilla extract stayed unchanged. Sensory feedback showed “Good” ratings for appearance, flavour, and aroma, with improved texture (two “Good,” one “Average”). The changes led to a softer mouthfeel, though slight density remained. These results align with Rosell et al. (2009), who found flaxseed enhances softness. Trial 3 showed clear progress, guiding refinements for Trial 4. (Table 3.1).

Trial 4 reduced flaxseed paste (64 g to 32 g) and oil (120 ml to 60 ml), while increasing choco chips (22 g to 45 g) to improve texture and flavour. Sensory evaluation by five panelists showed high scores for appearance and overall acceptability, with consistent 4s for texture, flavour, aroma, moistness, sweetness, and aftertaste. These changes created a soft, balanced muffin with enhanced sweetness. However, crust texture and filling distribution scored lower (3s), likely due to more flax seed paste and uneven spreading of choco chips. Findings align with Sudha et al. (2007), who noted low fat affects crust softness. Trial 4 showed strong progress with minor areas for refinement. (Table 3.2)

Trial 5 refined the recipe by reducing flaxseed paste from 32 g to 16 g and choco chips from 45 g to 22 g, aiming to lighten texture and improve filling distribution. Oil (60 ml) and flour (120 g) remained unchanged. Sensory evaluation by five panelists showed perfect scores for appearance and overall acceptability, with high ratings (4s and 5s) for texture and flavour. Aroma, moistness, sweetness, and aftertaste scored consistent 4s. Crust texture and filling distribution improved, likely due to reduced flaxseed and better mixing. These refinements reflect the principles of sensory optimization discussed by Rodrigues et al. (2024), who advocate for iterative adjustments based on consumer feedback to achieve ideal product profiles. Trial 5 emerged as the most balanced and optimized formulation. (Table 3.2)

Table 3.1: Informal Sensory Evaluation of vegan muffins for formulation Trial 1 to 3 (Qualitative Ratings: Good, Average, Bad)

Attribute	Criteria	Person 1			Person 2			Person 3		
		Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
Appearance	Colour, shape, and overall look	Good	Good	Good	Good	Good	Good	Good	Good	Good
Texture	Softness, crumb feel, and how it feels in the mouth	Average	Average	Good	Good	Good	Good	Average	Average	Average
Flavour	Sweetness, ingredient balance, and aftertaste	Average	Good	Good	Average	Good	Good	Average	Good	Good
Aroma	Freshness and how nice it smells	Good	Good	Good	Good	Good	Good	Good	Good	Good

Table 3.2: Sensory Evaluation of vegan muffins for formulation trial 4 and 5 by Hedonic Scale Ratings method by Panelists (5-point Hedonic Scale)

Attribute	Criteria	Panelist 1		Panelist 2		Panelist 3		Panelist 4		Panelist 5	
		Trial 14	Trial 15	Trial 14	Trial 15	Trial 14	Trial 15	Trial 14	Trial 15	Trial 14	Trial 15
Appearance	Colour, shape, and uniformity	5	5	4	5	5	5	4	5	4	5
Overall Acceptability	General impression of the product	5	5	5	5	4	5	5	5	5	5
Texture	Softness, crumb structure & mouthfeel	4	4	4	5	4	5	4	4	4	4
Flavor	Sweetness, balance of	4	4	4	4	4	5	4	5	4	4

	ingredients & aftertaste										
Aroma	Freshness and appealing scent	4	4	4	4	4	4	4	4	4	4
Moistness	Perceived moisture level	4	4	4	4	4	4	4	4	4	4
Sweetness Intensity	Degree of sweetness	4	4	4	4	4	4	4	4	4	4
Aftertaste	Lingering flavour	4	4	4	4	4	5	4	4	4	4
Crust Texture	Firmness and texture of the crust	3	4	3	5	3	5	3	5	3	4
Filling Distribution	Uniformity of added ingredients	3	4	3	5	3	5	3	5	3	4

3.3 Microbial Analysis of vegan muffins for formulation trial 5

Microbial analysis confirmed the safety and stability of the optimized vegan muffin sample. The Standard Plate Count (SPC) revealed two colonies on the test plate, corresponding to a microbial load of 200 CFU/g. This value is well within the acceptable limit for bakery products, as defined by standard food safety guidelines (Table 3.3; Fig 3.2). Vishali and Agarwal (2023) reported similarly low microbial counts in lotus seed-based muffins stored under hygienic conditions, supporting the effectiveness of clean handling and controlled baking environments.

Yeast or mold colonies and coliform were not detected, indicating excellent microbial quality and effective moisture control. The absence of fungal growth is consistent with the slightly acidic pH (6.41) and the use of proper baking temperatures, both of which inhibit fungal proliferation. Coliforms were also absent, confirming the hygienic handling of ingredients, utensils, and equipment throughout the preparation process. (Table 3.3; Fig 3.2) Selective plating for pathogenic organisms—including *Staphylococcus aureus*, *Salmonella* spp., and *Escherichia coli*—showed no growth, validating the absence of foodborne pathogens. These results align with findings by Islam & Banerjee. (2023), who reported no detectable pathogens in fortified muffin samples prepared under sterile conditions. The use of laminar airflow plating, sterilized glassware, and control plates further supports the reliability and reproducibility of the microbial results. (Table 3.3; Fig 3.2)

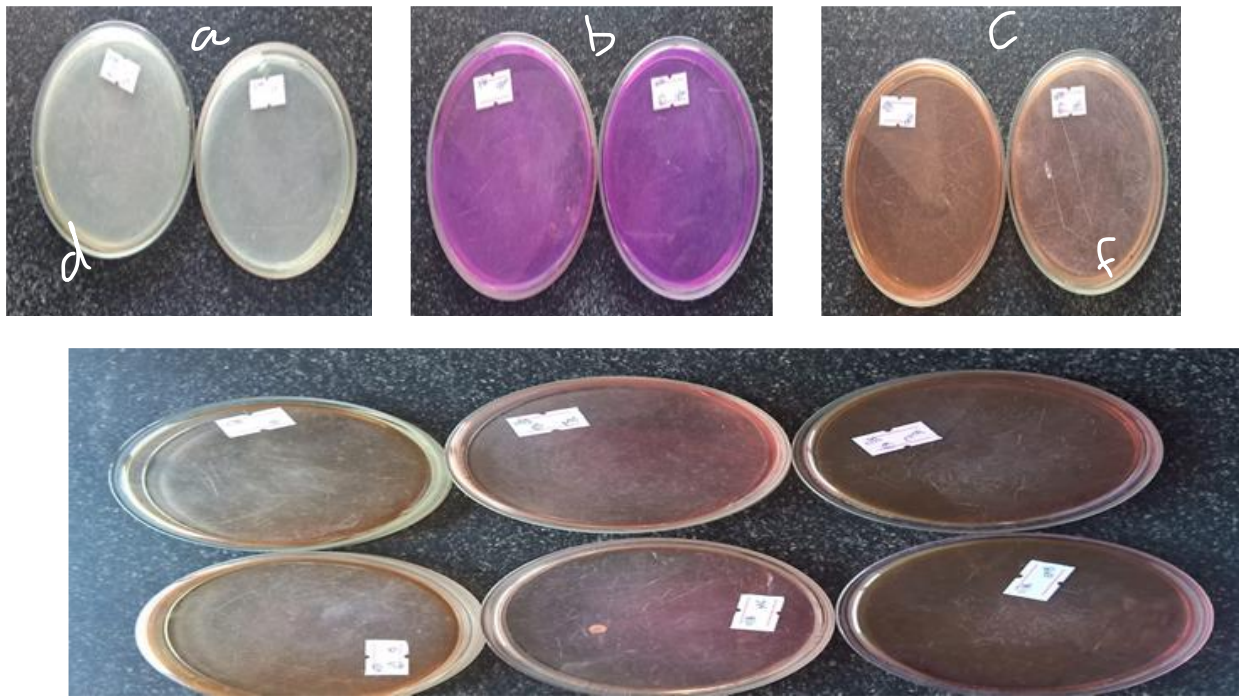


Fig 3.2: Plates showing negative growth of microbes from vegan muffins on Plate count agar medium(a), Rose Bengal chloramphenicol agar medium(b), Violet red bile agar medium(c), Salmonella–Shigella agar medium(d), Mannitol Salt Agar medium(e) and Eosin Methylene Blue agar medium(f)

Table 3.3: Microbial Analysis of Vegan Muffins for formulation trial 5

Category	Parameter	No. of colonies	Interpretation
Microbial Safety	Standard Plate Count (SPC)	200 CFU/g	Within acceptable limit; confirms microbial safety
	Yeast and Mold	Not detected	Excellent fungal control; effective moisture management
	Coliforms	Not detected	Hygienic handling; no fecal contamination
	<i>Staphylococcus aureus</i>	No growth	No pathogenic contamination
	<i>Salmonella spp.</i>	No growth	Safe for consumption; no foodborne pathogens detected
	<i>Escherichia coli</i>	No growth	Sterile preparation; ingredient safety validated

3.4 Nutritional Analysis of vegan muffins for formulation trial 5

The nutritional composition of the optimized vegan muffin was thoroughly analyzed using standard laboratory methods. Moisture content, as determined by the oven dry method, was found to be 28.24% (Table 3.4). This moderate moisture level contributes to softness and mouthfeel, aligning with findings by Islam & Banerjee. (2023), who reported 26–30% moisture in fortified muffins. Moisture above 25% enhances sensory appeal but may reduce shelf stability, as noted by Shukla & Verma (2024) and Vishali and Agarwal (2023).

Protein content was found to be 4.42% using the Kjeldahl method (Table 3.4). This value reflects the plant-based formulation and is consistent with Rabail et al. (2022), who reported 4.1–5.3% protein in garden cress-enriched muffins. The medium protein level suggests potential for enhancement through soy flour or legume-based isolates. Du & Zang. (2025) demonstrated that hempseed protein can significantly improve nutritional density, a finding aligned by Nikam et al. (2023) and Vishali and Agarwal (2023).

Fat content was measured as 14.7% using petroleum benzene extraction (Table 3.4). This is relatively high lipid content contributes to energy density and sensory quality. Similar fat levels (13–15%) were reported by Vishali and Agarwal (2023) in lotus seed-based muffins. Ahsan et al. (2024) emphasized that plant-based fats maintain mouthfeel while moderating caloric load. Shahid & Verma (2025) and Rabail & Khan. (2022) also highlighted the importance of healthy fats in vegan bakery products.

Ash content was calculated as 5.00%. This indicates the presence of mineral-rich ingredients like whole grains and seeds. Comparable ash values were reported by Islam et al. (2023) and Shukla & Verma (2024). Ahsan et al. (2024) linked higher ash content to the use of plant-based fat replacers, while Santos & Pereira (2025) found elevated ash in muffins containing melon peel flour (Table 3.4)

Crude fiber content was 5.3%, determined via the gravimetric method. This moderate fiber level supports digestive health and satiety. Rabail & Khan (2022) observed similar enhancements in muffins with functional seeds. Shukla & Verma. (2024) and Du & Zhang. (2025) noted that fruit and vegetable fibers improve both texture and shelf stability (Table 3.4)

Carbohydrate content, estimated by difference, was 42.34%, typical for bakery products. This value aligns with those reported by Vishali and Agarwal (2023) and Nikam & Deshmukh (2023) in lotus seed and oats-based muffins. Santos & Pereira (2025) and Du & Zhang (2025) emphasized the role of starches and oligosaccharides in contributing to energy and texture (Table 3.4)

The pH of the muffin was found to be 6.4. This slightly acidic range supports microbial safety and proper leavening. Similar pH values were reported by Rabail & Khan (2022), Kutlu & Yilmaz. (2024), and Islam & Banerjee (2023), confirming its suitability for vegan baked goods. (Table 3.4)

Table 3.4: Nutritional Analysis of Vegan Muffins for formulation trial 5

Category	Parameter	Result	Interpretation
Nutritional Profile	Moisture Content	28.24%	Moderate water retention; contributes to softness and mouthfeel
	Protein Content	4.42%	Modest protein level; aligns with plant-based formulations
	Fat Content	14.7%	High lipid content; enhances energy density and mouthfeel

	Ash Content	5.00%	Mineral-rich ingredients like whole grains and seeds
	Crude Fiber	5.3%	Supports digestive health and satiety
	Carbohydrate Content	42.34%	Typical for bakery products; contributes to texture and energy density
	pH Value	6.41	Slightly acidic; supports leavening and microbial safety

3.5 Shelf-life Study of vegan muffins for formulation trial 5

Shelf-life evaluation of the developed vegan muffins showed stable sensory and microbial quality under both ambient and refrigerated conditions. At room temperature ($25 \pm 2 \text{ }^\circ\text{C}$), muffins remained acceptable for 3–5 days with no spoilage and microbial growth, consistent with Shukla & Verma (2024) and Rabail & Khan (2022). After 5 days, vegan muffins get moistened and choco chips become molten. Refrigeration ($4 \pm 1 \text{ }^\circ\text{C}$) extended shelf-life for 4 to 8 days, maintaining safety and sensory appeal despite slight firmness due to starch retrogradation, as noted by Du & Zhang (2025) and Santos & Pereira (2025). The effectiveness of cold storage in preserving product integrity aligns with findings by Islam & Banerjee (2023) and Kutlu & Yilmaz (2024) (Table 3.5).

Table 3.5: Shelf-life study of Vegan Muffins for formulation trial 5

Category	Conditions of storage	No. of days muffins remain fresh	Interpretation
Storage Stability	Ambient ($25 \pm 2 \text{ }^\circ\text{C}$)	3–5 days	Stable aroma, texture, and appearance; no spoilage signs; no visible microbial growth
	Refrigerated ($4 \pm 1 \text{ }^\circ\text{C}$)	4–8 days	Stable aroma, texture, and appearance; no spoilage signs; no visible microbial growth but Slight firmness increase due to starch retrogradation

4. CONCLUSION

The vegan muffin developed in this study was healthy, safe from harmful microbes, and liked by taste testers. It followed modern food trends by using plant-based and clean-label ingredients. The formulation trial 5 recipe was the best among all trials because it had good taste, soft texture, balanced nutrition, and passed safety tests. Using flaxseed paste instead of eggs, right amount of sweetness, and proper baking time helped to make the muffin successfully. The outcomes of experimental tests on soy milk-based vegan choco chip muffins showed the successful development of a nutritionally complete and microbiologically safe plant bakery product.

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