*Original Research Article*

**EFFECT OF THE REPLACEMENT OF SUGAR ON DEVELOPMENT OF MUFFINS FROM MALTED RAGI FLOUR**

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ABSTRACT

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| **Aims**: This study aimed to develop and evaluate muffins enriched with malted ragi flour, sapota powder, and wheat flour for enhanced nutritional content and sensory acceptability, targeting functional food applications.  **Sample**: Three muffin samples (S1, S2, S3) were prepared with varying sweeteners (sugar, jaggery, honey) to assess nutritional and sensory differences.  **Study Design**: Experimental design with comparative analysis of proximate composition and sensory evaluation.  **Place and Duration of Study**: Department of Food Technology, Parul Institute of Applied Sciences, Parul University, Vadodara, Gujarat, India, conducted between January and March 2024.  **Methodology**: Malted ragi flour was prepared in laboratory, wheat flour, sapota powder, and other ingredients were purchased locally. Muffins were baked at 180°C for 15-20 minutes, with formulations differing in sweeteners: S1 (sugar), S2 (jaggery), S3 (honey). Proximate analysis of muffins was estimated by measuring moisture, ash, protein, fat, carbohydrates, sugar, calcium, and energy. Sensory evaluation used a 9-point hedonic scale, with academic staff assessing colour, taste, texture, flavour, appearance, and overall acceptability. Data were analyzed using SPSS and Microsoft Excel.  **Results**: Sample S1 showed the highest nutritional values: moisture (23.31 %), ash (2.68 %), protein (5.63 %), fat (9.69 %), carbohydrates (58.69 %), calcium (7.10 %), and energy (344.31 kcal/100g). Sensory scores were highest for S1 (overall acceptability: 9, p<0.05 compared to S2: 7, S3: 8). S2 had the lowest carbohydrates (54.78 %) and calcium (6.90 %).  **Conclusion**: Muffins with malted ragi, sapota powder, and wheat flour, especially S1, offer superior nutritional and sensory quality, suitable for commercial functional food production. Further studies on shelf life and scalability are recommended to enhance market viability. |

*Keywords: Muffins, Malting, Sweeteners, Sensory Evaluation*

1. INTRODUCTION

Muffins, known for their tender crumb, moist texture, and delightful sweetness, have become a beloved choice for quick snacks, breakfasts, or indulgent treats across the globe (Srilakshmi, 2018). As a cornerstone of the bakery sector, muffins have witnessed a surge in popularity, with the global bakery market projected to grow at a compound annual growth rate of 3.2% through 2028, driven by consumer demand for innovative, health-oriented products (Mordor Intelligence, 2023). This trend is fueled by heightened awareness of nutrition’s role in well-being, encouraging bakers to reformulate recipes with functional ingredients that deliver both sensory pleasure and nutritional benefits. Consumers increasingly seek vegan, gluten-free, or nutrient-fortified options, reflecting a shift toward sustainable and inclusive diets (Vinay & Singh, 2024). Sweeteners like sucrose remain pivotal in muffin production, enhancing flavor, promoting volume expansion, ensuring moisture retention, browning the crust, and extending shelf life. However, alternative sweeteners, such as natural fruit powders, are gaining traction for their dual role in taste and nutrition (Mariotti & Lucisano, 2014).

Finger millet (*Eleusine coracana*), commonly known as ragi, is a nutrient-dense small millet from the Poaceae family, extensively grown in India and parts of Africa (Chandra et al., 2016). Renowned for its exceptional calcium content up to 344 mg/100g, surpassing other cereals ragi is a powerhouse of dietary fiber, essential amino acids, antioxidants, and phytochemicals (Shobana et al., 2013). These attributes position ragi as an ideal candidate for fortifying bakery products, particularly for populations with calcium deficiencies or those seeking plant-based nutrition (Gull et al., 2016). Malting, a traditional processing technique, significantly enhances ragi’s nutritional value by reducing anti-nutritional factors like phytates and tannins, which inhibit mineral absorption (Chauhan & Sarita, 2018). The malting process involves soaking, germinating, and drying the grains, leading to increased levels of bioavailable proteins, free amino acids, vitamins (e.g., B-complex), and digestible carbohydrates (Karki et al., 2024). This makes malted ragi flour particularly suitable for baked goods, improving both nutritional quality and sensory attributes like texture and flavor.

Wheat (*Triticum spp.),* the most widely cultivated cereal globally, forms the structural foundation of most bakery products due to its unique gluten-forming properties and milling versatility (Shewry, 2009). Different wheat varieties serve distinct purposes: Triticum aestivum is preferred for bread and muffins, providing elasticity and volume, while Triticum durum is suited for pasta and flatbreads (Arendt & Zannini, 2013). Wheat flour acts as a carrier for micronutrients, enabling fortification with vitamins (e.g., folic acid) and minerals (e.g., iron), aligning with global initiatives to combat nutritional deficiencies (Brouns et al., 2012). In muffins, wheat flour ensures a balanced crumb structure, complementing nutrient-dense ingredients like ragi to create products that meet modern dietary expectations for health and convenience.

Sapota (*Manilkara zapota*), also known as sapodilla or chikoo, is a tropical fruit prized for its caramel-like sweetness and rich nutritional profile, including high levels of ascorbic acid, phenolic compounds, dietary fiber, and carbohydrates. Its perishability, however, poses challenges for fresh distribution, as sapota spoils within days of ripening, limiting its market reach (Baidya et al., 2020). To overcome this, sapota is processed into value-added forms such as powder, pulp, juice, or dried slices, which preserve its flavor, color, and nutrients while extending shelf life. Sapota powder, in particular, is gaining popularity in food applications, including bakery, dairy, and confectionery, due to its natural sweetness, which reduces the need for refined sugars, and its nutrient density, offering proteins, vitamins (A and C), and minerals (Punia Bangar et al., 2022). In muffins, sapota powder enhances sensory appeal and contributes to a nutrient-rich profile, making it a strategic ingredient for functional food development.

The integration of malted ragi flour, wheat flour, and sapota powder in muffin production represents a promising approach to creating vegan-friendly, nutrient-enriched bakery products. Ragi’s mineral wealth, particularly calcium and iron, addresses dietary gaps prevalent in cereal-dependent populations, while malting enhances its bioavailability and digestibility (Shobana et al., 2013). Sapota powder adds natural sweetness and fiber, appealing to health-conscious consumers seeking low-sugar alternatives (Siddiqui et al., 2020). Wheat flour ensures structural integrity and palatability, creating a cohesive product that balances nutrition and taste (Arendt & Zannini, 2013). This combination aligns with the global trend toward functional foods products designed to offer health benefits beyond basic nutrition, such as improved bone health, digestive wellness, and antioxidant protection (Granato et al., 2020).

Moreover, using indigenous ingredients like ragi and sapota promotes agricultural sustainability by valorizing underutilized crops, supporting local farmers, and reducing reliance on imported grains (FAO, 2018). The environmental benefits of such formulations are significant, as millets require less water and fewer inputs compared to conventional cereals, contributing to climate-resilient food systems (Saxena et al., 2018). In India, where ragi is a traditional staple, and sapota is widely available, these muffins offer a culturally relevant solution to modern nutritional challenges, such as micronutrient deficiencies and rising obesity rates due to processed foods (Misra et al., 2011).

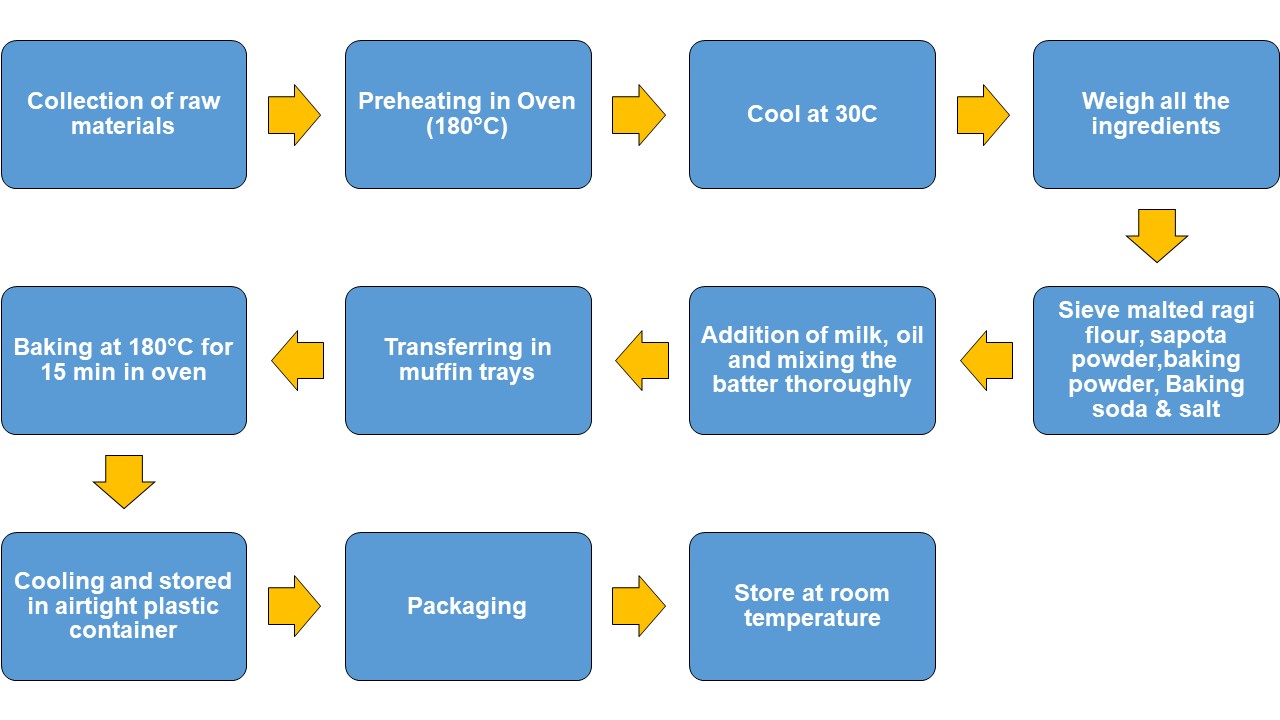
This study investigates the development of muffins incorporating malted ragi flour, sapota powder, and wheat flour, aiming to produce a nutrient-dense, sustainable product that meets contemporary consumer demands. By combining traditional ingredients with modern processing techniques, the research seeks to contribute to the growing field of functional bakery products, offering a scalable model for health-focused innovation in the food industry.

1. material and methods
   1. Collection of raw materials

Malted ragi flour was self-prepared and wheat flour, sapota powder, sugar, jaggery, honey, oil, milk, baking powder and baking soda were purchased from the local supermarket of Vadodara, Gujarat. The present study proposed research work on "Studies on development of nutritious muffins by indigenous food processing- Malting" was carried out at the Department of Food Technology of Parul Institute of Applied Science, Vadodara, Gujarat, India.

* + 1. **Preparation of Muffins**

To prepare muffins, collect good quality raw materials. Preheat the oven at 180 °C. Weigh all the ingredients. After weighing, sieve all dry ingredients. Then take a separate bowl and add all the dry ingredients malted ragi flour, wheat flour, sapota powder, sugar powder, baking powder and baking soda according to their measurement. Add wet ingredients like oil and milk. Start mixing with a spatula till they thicken and start forming into a thick batter. Gently scoop the thick batter into the greased muffin cups filling them till 3/4th. Bake for 15-20 minutes at 180°C. After baking, take the muffins out of the microwave and let it cool for 2-5 minutes. Store at a cool and dry place. The complete flow chart is provided in the Figure 1.



**Figure 1 Flow Diagram of Preparation of Muffins Preparation by Malting Process**

* + 1. **Recipe of muffins sample preparation**

**Table 1 Recipe of Muffins preparation**

|  |  |  |  |
| --- | --- | --- | --- |
| **Ingredients** | **Sample 1** | **Sample 2** | **Sample 3** |
| Malted ragi flour | 50gm | 50gm | 50gm |
| Sapota powder | 25gm | 25gm | 25gm |
| Wheat flour | 20gm | 20gm | 20gm |
| Sugar | 45gm | **-** | **-** |
| Jaggery | **-** | 40gm | - |
| Honey | - | - | 40ml |
| Baking powder | 3gm | 3gm | 3gm |
| Baking soda | 2gm | 2gm | 2gm |
| Oil | 20ml | 20ml | 20ml |
| Salt | 1gm | 1gm | 1gm |
| Milk | As required | As required | As required |

* + 1. **Proximate analysis of muffins**

Muffins were analyzed for moisture, ash, protein, fat, carbohydrate, energy, sugar and calcium contents according to the methods described in Association of Official Chemists (A.O.A.C., 2005). Determination of moisture is measured by FSSAI Manual. Fat was determined by Soxhlet method (A.O.A.C., 2015). The carbohydrate content of a food can be determined by calculating the percent remaining after all the other components have been measured. (A.O.A.C, 1995). Food energy value (kcal/100 g) was determined according to the method of Marero et al. (1998) using the factor (4 × %Protein) + (4 × %Carbohydrate) + (9 × %Fat).

* + 1. **Sensory evaluation of muffins**

Prepared product was evaluated for sensory characteristics in terms of appearance, color, flavor, after taste, texture and overall acceptability by academic staff members using 9- point hedonic scale. A 9-point Hedonic scale with accompanying descriptive phrases ranging from 9 for "like extremely" to 1 for "dislike extremely" was used to rate the product in order to make judgments. The acquired outcomes were noted on the sensory score card.

* + 1. **Statistical Analysis**

Both primary and secondary data were gathered in the course of the study. Data gathered was edited, coded and analyzed using Statistical Package for Social Sciences (SPSS) and Microsoft Excel and results presented into tables and figures.

1. results and discussion
   1. Chemical analysis of muffins

The nutritional profile of muffins formulated with malted ragi flour, sapota powder, and wheat flour was analyzed through proximate analysis, evaluating parameters such as moisture, ash, protein, fat, carbohydrates, sugar, calcium, and energy content. These measurements provide insights into the muffins’ nutritional value and suitability for health-conscious consumers (Fellows, 2017). The chemical composition of three muffin samples (S1, S2, S3) is summarized below:

**Table 2 Proximate analysis of Muffins**

|  |  |  |  |
| --- | --- | --- | --- |
| **Test parameter** | **S1** | **S2** | **S3** |
| Moisture (%) | 23.31 | 22.80 | 23.5 |
| Total ash (%) | 2.68 | 2.44 | 2.72 |
| Protein (%) | 5.63 | 5.21 | 4.90 |
| Fat (%) | 9.69 | 8.83 | 9.14 |
| Carbohydrates (%) | 58.69 | 54.78 | 57.43 |
| Sugar (%) | 11.92 | 11.51 | 12.8 |
| Calcium (%) | 7.10 | 6.90 | 7.05 |
| Energy kcal/ 100gm | 344.31 | 332.87 | 350.66 |

N=3

Sample S1 exhibited the highest calcium content at 7.10 %, followed by S3 (7.05 %) and S2 (6.90 %), reflecting ragi’s mineral richness (Chandra et al., 2016). Moisture levels ranged from 22.80% (S2) to 23.50% (S3), influencing texture and shelf life. S1 led in carbohydrates (58.69 %) and fat (9.69 %), while S2 had the lowest values (54.78 % and 8.83 %, respectively). Ash content, indicating mineral presence, peaked in S3 at 2.72 %. Protein content was highest in S1 (5.63 %) and lowest in S3 (4.90 %). Energy values ranged from 332.87 kcal/100g (S2) to 350.66 kcal/100g (S3). These nutrients carbohydrates for energy, proteins for growth, and calcium for bone health are essential for human nutrition (Srilakshmi, 2018).

* 1. Sensory evaluation of muffins

Sensory evaluation assesses food quality through human perception of attributes like appearance, aroma, taste, texture, and overall acceptability (Lawless & Heymann, 2010). For the muffins, a 9-point hedonic scale was used, where 1 indicates "dislike extremely" and 9 indicates "like extremely," conducted by a trained panel to ensure reliable organoleptic feedback.

**Table 3 Sensory Evaluation of prepared muffin samples**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sample code** | **Colour** | **Taste** | **Texture** | **Flavour** | **Appearance** | **Overall acceptability** |
| S1 | 9 | 8 | 8 | 9 | 8 | 9 |
| S2 | 9 | 6 | 7 | 7 | 8 | 7 |
| S3 | 9 | 8 | 7 | 8 | 7 | 8 |

N=3

Sample S1 scored highest in overall acceptability (9, "like extremely"), excelling in colour (9) and flavour (9), with strong ratings for taste (8), texture (8), and appearance (8). Sample S3 followed with an overall score of 8 ("like very much"), matching S1’s colour (9) and performing well in taste (8) and flavour (8). Sample S2 scored lowest at 7 ("like moderately"), with a notably lower taste score (6), though its colour (9) and appearance (8) were competitive. These results suggest that S1’s formulation balanced sensory attributes effectively, likely due to the synergy of malted ragi’s nutty flavour, sapota’s sweetness, and wheat’s structure (Shobana et al., 2013; Punia Bangar et al., 2022).

The muffins’ nutritional profile highlights their potential as a functional food. S1’s high calcium (7.10 %), carbohydrate (58.69 %), and energy content (344.31 kcal/100g) make it a nutrient-dense option, enhanced by malted ragi’s bioavailable minerals and sapota’s vitamins (Karki et al., 2024; Jadhav, 2018). The sensory superiority of S1 suggests that its ingredient ratios optimized palatability, critical for consumer acceptance in bakery products (Arendt & Zannini, 2013). The inclusion of malted ragi flour improves digestibility and nutrient absorption, while sapota powder adds natural sweetness and fiber, reducing reliance on refined sugars. Wheat flour provides structural integrity and serves as a nutrient carrier, aligning with trends toward fortified baked goods.

These muffins offer health benefits, including improved bone health (calcium), sustained energy (carbohydrates), and muscle repair (proteins), alongside therapeutic properties from sapota’s antioxidants. Their appetizing texture and digestible nature support large-scale production, particularly for vegan and health-focused markets. The findings advocate for using malted ragi, sapota powder, and wheat flour to develop high-quality, nutritious muffins suitable for commercial applications.

1. Conclusion

The incorporation of malted ragi flour, sapota powder, and wheat flour in muffin formulations produces a nutrient-dense bakery product with significant health benefits. Proximate analysis revealed that sample S1 surpassed S2 and S3 in key nutritional parameters, demonstrating higher levels of moisture (23.31 %), ash (2.68 %), fat (9.69 %), protein (5.63 %), carbohydrates (58.69 %), calcium (7.10 %), and energy (344.31 kcal/100g), positioning S1 as a superior functional food that meets consumer demand for nutritious and palatable baked goods.Malting ragi enhances its nutritional profile by reducing anti-nutritional factors, such as phytates, while increasing bioavailable vitamins (B-complex, C), minerals (calcium, manganese, copper, zinc), and proteins, thereby improving digestibility and nutrient absorption. Sapota powder further enriches muffins with dietary fiber, proteins, and calcium, enhancing both nutritional value and sensory appeal through its natural sweetness and flavor. Wheat flour provides structural integrity and acts as a carrier for micronutrients, ensuring a well-balanced product. The elevated calcium, protein, and energy content of these muffins makes them a promising solution for addressing dietary deficiencies, particularly in populations dependent on cereal-based diets. The success of the S1 formulation suggests its potential for scalable commercial production, offering a sustainable approach to utilizing underutilized crops like ragi and sapota. Future research should focus on shelf-life stability and broader consumer acceptance to confirm the market viability of these muffins. This study establishes that combining malted ragi flour, sapota powder, and wheat flour yields muffins with exceptional nutritional and functional qualities, paving the way for innovative, health-focused bakery products.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References

Arendt, E. K., & Zannini, E. (2013). Cereal grains for the food and beverage industries. Woodhead Publishing.

Association of Official Analytical Chemists. (1995). Official methods of analysis of AOAC International (16th ed.). AOAC International.

Association of Official Analytical Chemists. (2005). Official methods of analysis of AOAC International (18th ed.). AOAC International.

Association of Official Analytical Chemists. (2015). Official methods of analysis of AOAC International (20th ed.). AOAC International.

Baidya, B. K., Mahato, A., Pattnaik, R. K., and Sethy, P. (2020). A Review of physiological and biochemical changes related to ripening along with postharvest handling and treatments of Sapota. Journal of Pharmacognosy and Phytochemistry, 9(4), 2030-2035. <https://doi.org/10.22271/phyto.2020.v9.i4ab.12054>

Brouns, F., Hemery, Y., Price, R., & Anson, N. M. (2012). Wheat aleurone: Separation, composition, health aspects, and potential food use. Critical Reviews in Food Science and Nutrition, 52(6), 553–568. <https://doi.org/10.1080/10408398.2011.589540>

Chandra, D., Chandra, S., Pallavi, & Sharma, A. K. (2016). Review of finger millet (Eleusine coracana (L.) Gaertn): A powerhouse of health benefiting nutrients. Food Science and Human Wellness, 5(3), 149-155. <https://doi.org/10.1016/j.fshw.2016.05.004>

Chauhan, E. S. & Sarita. (2018). Effects of processing (germination and popping) on the nutritional and anti-nutritional properties of finger millet (Eleusine coracana). Current Research in Nutrition and Food Science Journal, 6(2), 566-572. doi : <http://dx.doi.org/10.12944/CRNFSJ.6.2.30>

FAO. (2018). The state of food and agriculture 2018: Migration, agriculture and rural development. Food and Agriculture Organization of the United Nations.

Fellows, P. J. (2017). Food processing technology: Principles and practice (4th ed.). Woodhead Publishing.

Food Safety and Standards Authority of India. (2015). Manual of methods of analysis of foods: Milk and milk products. Ministry of Health and Family Welfare, Government of India. <https://www.fssai.gov.in/upload/uploadfiles/files/Manual_Milk_Products_2015.pdf>

Granato, D., Barba, F. J., Bursać Kovačević, D., Lorenzo, J. M., Cruz, A. G., & Putnik, P. (2020). Functional foods: Product development, technological trends, efficacy testing, and safety. Annual Review of Food Science and Technology, 11, 93–118. <https://doi.org/10.1146/annurev-food-032519-051708>

Gull, A., Jan, R., Nayik, G. A., Prasad, K., & Kumar, P. (2016). Significance of finger millet in nutrition and health: A review. Journal of Food Science and Technology, 53(5), 2261–2268.

Jadhav, S. S. (2018). Value added products from sapota: A review. International Journal of Food Science and Nutrition, 3(5), 114-120.

Karki, S., Dangal, A., Pokharel, A., Dhakal, L., & Timsina, P. (2024). The effect of germination on the nutritional quality and sensory evaluation of finger millet (Elusine coracana L., var. Kabre-1) malt incorporated biscuit. Cogent Food & Agriculture, 10(1). <https://doi.org/10.1080/23311932.2024.2419149>

Lawless, H. T., & Heymann, H. (2010). Sensory evaluation of food: Principles and practices (2nd ed.). Springer.

Marero, L. M., Payumo, E. M., Aguinaldo, A. R., & Homma, S. (1998). Nutritional characteristics of weaning foods prepared from germinated cereals and legumes. Journal of Food Science, 53(5), 1390–1395. <https://doi.org/10.1111/j.1365-2621.1988.tb09285.x>

Mariotti, M., & Lucisano, M. (2014). Sugar and sweeteners. Bakery products science and technology, 199-221.

Misra, A., Singhal, N., Sivakumar, B., Bhagat, N., Jaiswal, A., & Khurana, L. (2011). Nutrition transition in India: Secular trends in dietary intake and their relationship to diet-related chronic diseases. Journal of Diabetes, 3(4), 278–292. <https://doi.org/10.1111/j.1753-0407.2011.00139.x>

Mordor Intelligence. (2023). Bakery products market - Growth, trends, and forecasts (2023-2028). <https://www.mordorintelligence.com/industry-reports/bakery-products-market>

Punia Bangar, S., Sharma, N., Kaur, H., Kaur, M., Sandhu, K. S., Maqsood, S., & Ozogul, F. (2022). A review of Sapodilla (Manilkara zapota) in human nutrition, health, and industrial applications. Trends in Food Science and Technology, 127, 319-334. <https://doi.org/10.1016/j.tifs.2022.05.016>

Saxena, R., Vanga, S. K., Wang, J., Orsat, V., & Raghavan, V. (2018). Millets for food security in the context of climate change: A review. Sustainability, 10(7), 2228. <https://doi.org/10.3390/su10072228>

Shewry, P. R. (2009). Wheat. Journal of Experimental Botany, 60(6), 1537–1553. <https://doi.org/10.1093/jxb/erp058>

Shobana, S., Krishnaswamy, K., Sudha, V., Malleshi, N. G., Anjana, R. M., Palaniappan, L., & Mohan, V. (2013). Finger millet (Eleusine coracana L.): A review of its nutritional properties, processing, and plausible health benefits. Advances in Food and Nutrition Research, 69, 1-39. <https://doi.org/10.1016/B978-0-12-410540-9.00001-6>

Siddiqui, S. A., Anwar, F., & Mahmood, Z. (2020). Sapodilla (Manilkara zapota): Nutritional and therapeutic perspectives. Journal of Food Biochemistry, 44(8), e13245. <https://doi.org/10.1111/jfbc.13245>

Srilakshmi, B. (2018). Food science (6th ed.). New Age International Publishers.

GM, V., & Singh, A. K. (2024). Effect of ghee residue powder and pearl millet flour substitution on rheological, textural, and sensorial characteristics of eggless Muffin. Journal of Food Processing and Preservation, 2024(1), 5519265. <https://doi.org/10.1155/2024/5519265>