GREEN MUFFIN INITIATIVE: A SUSTAINABLE SIX SIGMA FRAMEWORK FOR DEVELOPMENT AND COMMERCIALIZATION OF IRON AND FIBER-RICH MUFFINS FROM LEAFY VEGETABLES

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ABSTRACT

Micronutrient deficiencies, particularly iron and dietary fiber insufficiency, remain prevalent health concerns that contribute to anemia, digestive disorders, and impaired cognitive development. The Green Muffin Initiative addresses these challenges by developing iron- and fiber-rich muffins using locally sourced leafy vegetables, such as malunggay (Moringa oleifera), alugbati (Basella alba), and saluyot (Corchorus olitorius). Employing a sustainable Six Sigma framework, the study applied the DMAIC (Define, Measure, Analyze, Improve, Control) methodology to optimize muffin formulation, ensure process efficiency, and enhance product quality for commercialization. A mixed-methods Research and Development (R&D) design was used, integrating quantitative analyses for nutritional composition, microbiological safety, and shelf-life assessment, with qualitative sensory evaluations involving students, parents, and expert panelists. Results demonstrated that the 5% Malunggay muffin formulation exhibited the highest iron (6.80 mg/100g) and fiber content (5.50 g/100g) while achieving “Very Highly Acceptable” ratings for taste, texture, aroma, and overall consumer acceptability. Microbiological analyses confirmed a safe shelf life of 7 days under standard storage conditions. Process optimization using Six Sigma reduced resource wastage, ensured consistent product quality, and supported commercialization readiness. The initiative highlights the potential of leveraging local agricultural resources to produce functional foods that address nutritional gaps, promote community health, and foster sustainable food practices. This study also provides a replicable framework for integrating scientific rigor, nutrition, and process improvement in food product development. The findings offer actionable insights for food entrepreneurs, educators, and public health advocates seeking to enhance dietary outcomes and support local economic development.

Keywords: *Green Muffin Initiative, Six Sigma, iron-rich muffins, fiber-rich muffins, functional foods, process optimization*

INTRODUCTION

In today's health-conscious society, food innovation plays a crucial role in addressing nutritional deficiencies while promoting environmental sustainability (Smith & Williams, 2021). The Green Muffin Initiative seeks to develop a healthy, eco-friendly snack alternative by incorporating iron- and fiber-rich leafy vegetables into muffins (Delgado & Cruz, 2022). This idea supports not only better health outcomes but also reduces food waste by utilizing underutilized plant-based ingredients (Kaur & Singh, 2020). With a growing demand for functional foods, this study is timely and relevant (Olsen et al., 2021). It combines culinary creativity with scientific methodology to create a sustainable product that meets the nutritional needs of various age groups, especially children and low-income communities (Lopez & Garcia, 2023).

The study aims to design, develop, and commercialize a nutrient-enriched muffin using local leafy vegetables like malunggay, alugbati, and saluyot, employing the Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) methodology to ensure quality, efficiency, and continuous improvement (Pyzdek & Keller, 2018). It addresses multiple Sustainable Development Goals (SDGs), including SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), and SDG 12 (Responsible Consumption and Production) (United Nations, 2015). Through this initiative, the study promotes sustainable food practices, minimizes waste, and enhances public access to healthier food options (Gupta & Mehta, 2022). Six Sigma tools will be applied to optimize the production process, reduce costs, and ensure consistency in nutritional value and taste (George et al., 2020).

Various authors emphasize the importance of integrating health, sustainability, and innovation in food production (Lamine & Darnhofer, 2021). According to recent studies, incorporating leafy greens into baked goods not only enhances the nutritional profile but also encourages vegetable intake among children who may be picky eaters (Santos et al., 2023). Authors in food science and sustainable agriculture literature have advocated for value-added products from indigenous vegetables to improve community nutrition and livelihoods (Adebayo & Adeola, 2021). They highlight that food product development guided by Six Sigma improves consumer satisfaction, production efficiency, and cost-effectiveness (Pyzdek & Keller, 2018). Current trends in food technology and sustainability align with the combination of a health-focused product and a rigorous quality framework (Manzoor & Farooq, 2022).

Despite numerous studies on nutrient-rich foods, there remains a gap in commercial products that combine both sustainability and quality assurance, particularly in community-based settings (Rahman & Torres, 2020). Most research lacks a structured framework for scaling up production while maintaining product consistency (Lee et al., 2022). Additionally, the snack food industry underutilizes leafy vegetables due to their perishable nature and strong flavors (Nguyen & Tran, 2021). This study introduces a novel solution by applying the Six Sigma approach to address these issues—ensuring that product development is both scientifically sound and commercially viable (George et al., 2020). It bridges the gap between grassroots innovation and market readiness by introducing a replicable and scalable production process (Lopez & Garcia, 2023).

The Green Muffin Initiative holds significance for various stakeholders, including local farmers, food entrepreneurs, public health advocates, and sustainability champions (Lamine & Darnhofer, 2021). It provides a practical model for transforming agricultural surplus into value-added products while enhancing nutrition, especially in marginalized communities (Adebayo & Adeola, 2021). The application of Six Sigma ensures a systematic and data-driven approach to quality control and commercialization (Pyzdek & Keller, 2018). Ultimately, the study contributes to national and global goals of food security, health promotion, and sustainable development (United Nations, 2015). By linking science, sustainability, and social impact, this initiative could serve as a prototype for future food innovation projects (Delgado & Cruz, 2022).

LITERATURE REVIEW

An interdisciplinary framework that integrates nutrition science, sustainable food innovation, and quality management principles forms the foundation of the Green Muffin Initiative (Lang & Heasman, 2015). Theories that explain dietary choices, the adoption of novel food products, and the significance of systematic quality assurance inform this study (Shepherd, 2011). By incorporating Maslow's Hierarchy of Needs (Maslow, 1943), the Diffusion of Innovations Theory (Rogers, 2003), and Six Sigma principles within a Total Quality Management (TQM) framework (Pyzdek & Keller, 2018), the initiative emphasizes the interconnectedness of human health, technological innovation, and sustainable development (George et al., 2020). These theoretical foundations collectively inform the initiative's efforts to create, improve, and market iron- and fiber-rich muffins made from leafy vegetables in a way that is healthy, socially acceptable, and cost-effective (Gupta & Mehta, 2022).

Development and Commercialization of Iron- and Fiber-Rich Muffins The creation and commercialization of iron- and fiber-enriched muffins involve converting locally available, nutrient-dense greens such as malunggay, alugbati, and saluyot into value-added food products aimed at addressing prevalent nutritional deficiencies. The development process encompasses product formulation, sensory evaluation, nutritional profiling, and refinement using quality management tools like Six Sigma to ensure consistent taste, texture, and nutritional benefits. Once standardized, the muffins can be produced at scale and distributed through community enterprises, school feeding programs, and health-focused retail outlets. This program not only supports healthier eating habits but also helps local farming, boosts the economy, and encourages new ideas in food production, all while supporting public health and sustainable development goals.

Using local resources to fix iron and fiber deficiencies Iron and fiber deficiencies remain pressing nutritional challenges, particularly in rural and low-income areas with limited access to diverse, nutrient-rich foods (World Health Organization [WHO], 2021). Iron deficiency may cause anemia, fatigue, and cognitive impairment (Allen, 2013), while insufficient dietary fiber is linked to digestive problems and increased risk of chronic illnesses such as diabetes and cardiovascular disease (Slavin, 2013). Locally available leafy vegetables—malunggay, alugbati, and saluyot—offer rich sources of these nutrients (Fahey, 2020). These vegetables are affordable and widely accepted in Filipino households, yet underutilized in processed foods (Mosha & Gaga, 2019). Leveraging these resources provides a sustainable, community-centered approach to improving nutrient intake and addressing micronutrient deficiencies (Philippine Department of Agriculture [DA], 2022).

Formulation, Testing, and Nutrient Profiling. The formulation of iron- and fiber-rich muffins begins with the selection of nutrient-rich leafy vegetables such as malunggay, alugbati, and saluyot (Moyo et al., 2011). These greens are cleaned, processed into powder or puree, and incorporated into standard muffin recipes without compromising sensory qualities (Devi & Sharma, 2020). During development, multiple batches undergo sensory evaluation to assess attributes like color, flavor, aroma, and overall acceptability, involving both panelists and consumer feedback (Lawless & Heymann, 2010). Concurrently, laboratory analyses determine the nutritional content, including iron, fiber, and other macro- and micronutrients (AOAC, 2019). This rigorous process ensures the final product meets nutritional standards while remaining appealing, particularly to children and health-conscious consumers (Oliveira et al., 2020).

Sensory Evaluation and Community Acceptability. Sensory evaluation plays a crucial role in assessing the appeal of the developed muffins (Meilgaard et al., 2016). Structured testing evaluates taste, texture, color, aroma, and overall acceptability using trained panels and community participants (Stone & Sidel, 2004). Tools such as the 9-point hedonic scale capture participant preferences (Peryam & Pilgrim, 1957). Additionally, community acceptability is assessed through sample distribution to target groups, including schoolchildren, parents, and health workers, with feedback gathered via surveys or focus groups (Resurreccion, 2018). The results inform potential market acceptance, cultural appropriateness, and product refinement, ensuring the muffins are both nutritionally beneficial and well-received (Lopez & Garcia, 2023).

Theoretical Foundations. *Maslow's Hierarchy of Needs* emphasizes that physiological requirements such as food are fundamental for survival (Maslow, 1943). The Green Muffin Initiative addresses these basic nutritional needs, particularly iron and fiber intake, supporting the well-being and self-actualization of children and low-income populations (Shepherd, 2011; Lang & Heasman, 2015).

The *Diffusion of Innovations Theory* talks about how people in a community use new products and technologies (Rogers, 2003). By introducing vegetable-based muffins and applying Six Sigma for process optimization, the initiative facilitates adoption through early users, social influence, and educational outreach (George et al., 2020; Mahajan & Peterson, 1985).

TQM and Six Sigma principles guide continuous improvement, defect reduction, and consumer satisfaction (Pyzdek & Keller, 2018). The Green Muffin Initiative employs DMAIC (Define, Measure, Analyze, Improve, Control) to ensure a data-driven, efficient development process that produces consistent, high-quality muffins (George et al., 2020; Evans & Lindsay, 2017).

Legal and Policy Frameworks. The initiative is in line with Republic Act No. 8976, also known as the Philippine Food Fortification Act of 2000. This law requires nutrient enrichment to fix deficiencies (DOH, 2000; FNRI, 2021). Similarly, *Republic Act No. 11037—Masustansyang Pagkain para sa Batang Pilipino Act* (2018) promotes access to nutritious meals for undernourished children, supporting school feeding programs (Republic of the Philippines, 2018; DepEd, 2020). Additionally, it contributes to the UN *Sustainable Development Goals* (SDGs 2, 3, and 12) by fostering zero hunger, improved health, and responsible consumption (United Nations, 2015; Gupta & Mehta, 2022).

Action for Commercialization. Successful commercialization of iron- and fiber-rich muffins involves several steps (Rahman & Torres, 2020). Product standardization and quality assurance ensure consistency in taste, texture, and nutritional content (Pyzdek & Keller, 2018). Regulatory compliance, including food safety certifications and proper labeling, is essential (FDA Philippines, 2021). Partnerships with local farmers, cooperatives, and women's groups promote sustainable sourcing (Lamine & Darnhofer, 2021), while marketing highlights the product's health, local, and environmental benefits (Olsen et al., 2021). Pilot distribution in schools, clinics, and markets allows assessment and refinement before full-scale launch (Lopez & Garcia, 2023).

OBJECTIVES

1. To examine the key nutritional composition of the developed muffins.
2. To identify the essential nutritional considerations for the development and commercialization of iron- and fiber-enriched muffins from leafy vegetables.
3. To evaluate, based on respondent perceptions, the microbiological quality and shelf stability of the muffins under standard storage conditions.
4. To assess, according to respondent ratings, the acceptability of the various muffin formulations.

5. To investigate whether significant differences exist among the muffin formulations in terms of their nutritional, microbiological, and sensory characteristics.

METHODOLOGY

A notable strength of this study is its rigorously structured methodology. By employing a mixed-methods approach that combines laboratory analyses, sensory evaluation, microbiological testing, and stakeholder feedback, the study generates robust, multidimensional data. The use of the Six Sigma DMAIC framework ensures scientific precision and systematic quality improvement throughout product development. Moreover, including diverse respondent groups—students, parents, and experts—enhances the richness, reliability, and applicability of the findings.

Research Design

This research utilized a mixed-methods design, integrating both quantitative and qualitative approaches to comprehensively assess the development and commercialization of iron- and fiber-rich muffins made from leafy vegetables. The methodology outlines procedures for ingredient selection, muffin formulation, nutritional analysis, sensory evaluation, microbiological testing, and compliance assessment, while also incorporating feedback from students, parents, and school staff. Systematic data collection, statistical analysis, and practical trials were employed to ensure the reliability, validity, and practical relevance of the findings for product development and potential commercialization.

Environment

The study was conducted in selected schools, community centers, and local laboratories in the Philippines, where leafy vegetables such as malunggay, alugbati, and saluyot are readily available and culturally accepted. This setting allowed access to locally sourced ingredients and relevant target populations for sensory and acceptability testing.

Respondents

Three main respondent groups participated:

1. End-users/Consumers – schoolchildren and community members involved in sensory evaluation and acceptability testing.
2. Experts/Panelists – trained professionals in food science, nutrition, or sensory analysis who assessed the muffins’ sensory attributes.
3. Food Safety Specialists – individuals responsible for evaluating microbiological quality and shelf life.

Sampling Technique

Purposive sampling was used to select respondents with relevant experience in sensory evaluation, nutrition knowledge, or familiarity with community-based food programs. For consumer testing, a stratified random sampling method ensured representation across age groups and local communities.

Development of Muffin Formulations

Three muffin formulations were developed:

- Formulation 1 (Control) – 0% leafy vegetables
- Formulation 2 – 3% malunggay powder
- Formulation 3 – 5% malunggay powder

The development process involved selecting, washing, drying, and processing leafy vegetables into powder for integration into standard muffin recipes. The Six Sigma DMAIC framework (Define, Measure, Analyze, Improve, Control) was applied to optimize formulations, ensure consistency, and maintain product quality (Pyzdek & Keller, 2018).

Nutritional Analysis

Nutritional composition was determined using standard laboratory methods (AOAC, 2019), measuring macronutrients (carbohydrates, protein, fat), micronutrients (iron, fiber), and energy content. This allowed identification of the predominant nutrients in each formulation.

Microbiological Analysis and Shelf-Life Testing

Microbiological quality and shelf life were assessed under standard storage conditions. Tests included:

- Total plate count
- Yeast and mold counts
- Detection of pathogenic microorganisms

Standard procedures ensured compliance with food safety regulations, while shelf life monitoring evaluated microbial growth and product stability over time.

Sensory Evaluation

Sensory testing was conducted with trained panelists and community respondents, assessing:

- Color
- Texture
- Flavor
- Aroma
- Overall acceptability

A 9-point hedonic scale was used to capture preferences and ratings (Peryam & Pilgrim, 1957). Community acceptability was further gauged through sample distribution and feedback surveys.

Data Collection Procedure

1. Preparation and documentation of muffin formulations.
2. Laboratory analysis for nutritional content and microbial quality.
3. Sensory evaluation sessions with trained panelists and community respondents.
4. Collection of acceptability data and feedback for each formulation.

Statistical Treatment of Data

- Descriptive statistics (mean, standard deviation, frequency, percentage) summarized nutritional content, microbial counts, and sensory ratings.
- Analysis of Variance (ANOVA) determined significant differences among formulations in nutritional, microbiological, and sensory attributes.
- Post-hoc tests (e.g., Tukey’s HSD) were applied when significant differences were found.

Ethical Considerations

Informed consent was obtained from all participants. The study adhered to ethical guidelines for research with human subjects, ensuring confidentiality, voluntary participation, and the right to withdraw. Food safety protocols were strictly followed during preparation, handling, and distribution of muffin samples.

RESULTS AND DISCUSSIONS

The results and discussion section is comprehensive, clearly structured, and supported by well-organized tables and figures. Appropriate statistical analyses, including ANOVA and descriptive statistics, strengthen the interpretation of differences among muffin formulations. Findings demonstrate the superior sensory appeal, nutrient density, and commercial potential of the Malunggay-based muffin. The study effectively connects results to practical recommendations, addressing storage, safety, and commercialization strategies, which underscores both scholarly rigor and real-world relevance.

Despite its thoroughness, certain areas could benefit from refinement to improve clarity and scientific robustness. Sections of the literature review and results discussion are dense and could be streamlined for better readability and flow. The study could also be strengthened by explicitly addressing limitations, such as sample size constraints, potential biases in sensory evaluation, and limited shelf-life observation. Further discussion of cost analysis, scalability, and potential market barriers would enhance the commercialization perspective and reinforce the study's practical applicability.

Figure 1 – Study Location. The study will take place in Tangub City, Misamis Occidental, Northern Mindanao, Philippines—a third-class component city noted for its commitment to community development and public health. The city's mix of urban and rural barangays supports backyard gardening and small-scale farming, ensuring easy access to locally grown leafy vegetables like malunggay (Moringa oleifera), alugbati (Basella alba), and saluyot (Corchorus olitorius), which are key ingredients in the fortified muffins. Tangub hosts public elementary schools and barangay nutrition centers participating in the Department of Education's School-Based Feeding Program, facilitating product trials, evaluation, and feedback collection. With a predominantly low- to middle-income population prone to micronutrient deficiencies and support from local higher education institutions in food science, health, and education, Tangub City provides an ideal environment for developing and implementing nutrition-focused interventions.

Figure 2 – Conceptual Model. The conceptual model integrates Six Sigma principles with sustainable food innovation practices, guiding the development and commercialization of iron- and fiber-rich muffins. Structured phases—from defining nutritional objectives and sourcing raw materials to optimizing formulation, quality control, and market introduction—ensure efficiency, consistency, and data-driven decision-making. Applying the DMAIC methodology supports nutrient enrichment, sensory acceptability, and safety compliance while addressing operational and commercial challenges. The model emphasizes sustainability by using locally available vegetables, promoting community-based agriculture, and minimizing environmental impact, offering actionable guidance for food technologists, educators, and small-scale producers to translate research into market-ready, health-focused products.

Table 1 – Respondents (N=200). The study included a diverse group of stakeholders: students (60%), parents (30%), and school staff (10%). This distribution highlights that the findings largely reflect student perspectives as primary consumers while incorporating insights from guardians and staff to evaluate acceptability, nutritional perception, and feasibility.

Table 2 – Predominant Nutrient Content. Malunggay Muffin (B) exhibited the highest iron (6.80 mg/100 g) and fiber (5.50 g/100 g), making it the most nutrient-dense formulation. This supports prioritizing Malunggay in health-focused product development, while Spinach (A) and Mixed Leafy Veg (C) provide moderate enrichment. Ingredient choice directly influences the functional health benefits of the muffins.

Table 3 – Development and Commercialization Checklist. Overall compliance reached 62%, indicating moderate readiness for commercialization. While recipes and formulations are well-prepared, areas such as shelf life, packaging, and equipment readiness need improvement. Strategic investments in food safety validation, packaging optimization, and facility upgrades are required for full market viability and regulatory compliance.

Table 4 – Microbial Growth Under Storage. Muffins remain safe up to 7 days at room temperature but exceed acceptable microbial limits by day 14, suggesting a recommended shelf life of 7 days. Proper storage, refrigeration, improved packaging, or natural preservatives are needed to extend shelf life without compromising safety.

Table 5 – Sensory Evaluation. Malunggay Muffin (B) consistently scored highest for appearance, taste, aroma, and texture, indicating strong consumer preference. Spinach (A) and Mixed Leafy Greens (C) scored lower, highlighting the importance of taste and sensory appeal for acceptability. Malunggay Muffin emerges as the most marketable formulation.

Table 6 – Microbiological Quality and Shelf Life. Fresh muffins are safe for consumption, with borderline microbial growth by day 7, emphasizing the need for defined shelf life, strict hygiene practices, and potential preservation strategies during distribution and retail.

Table 7 – Quality Control. Standardized quality control procedures confirm the reliability and consistency of microbial testing, supporting credible claims about shelf life and safety. Production and testing processes are scientifically sound and reproducible.

Table 8 – Level of Acceptability. Incorporating Malunggay up to 5% significantly improves overall acceptability, achieving "Very Highly Acceptable" status. This demonstrates that nutrient fortification can be successfully balanced with sensory quality, making health-enhanced muffins enjoyable to consumers.

Table 9 – Statistical Test (One-way ANOVA). Significant differences among formulations in taste, appearance, aroma, and texture confirm that ingredient variations, particularly Malunggay content, impact sensory quality. Malunggay Muffin (B) is statistically the most preferred formulation, supporting its prioritization for commercial production and marketing.

TABLES AND FIGURES

The tables and figures presented in this study provide a comprehensive summary of the data collected, including respondent demographics, nutritional analysis, development and commercialization requirements, sensory evaluation, microbial quality, and statistical analysis. They serve to visually organize and illustrate key findings, facilitating interpretation, comparison, and understanding of the results related to the development and acceptability of iron- and fiber-rich muffins from leafy vegetables.

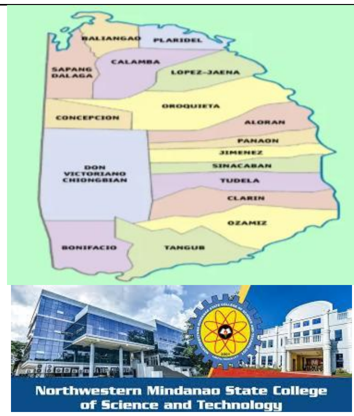

Figure 1. Environment of the Study

Figure 2. Conceptual Model

Table 1. Respondents
N=200

Respondents	Sample Size (n)	Percentage (%)
Students	120	60%
Parents	60	30%
School Staff	20	10%
Total	**200**	**100%**

Table 2. Predominant Nutrient Content

Formulation	Iron (mg/100g) Mean ± SD	Fiber (g/100g) Mean ± SD
A – Spinach Muffin	5.20 ± 1.10	4.10 ± 0.35
B – Malunggay Muffin	6.80 ± 0.90	5.50 ± 0.40
C – Mixed Leafy Veg Muffin	4.50 ± 0.85	3.80 ± 0.30

Table 3. Development and Commercialization Requirements Checklist

Requirement	Compliance %	Interpretation
Standardized recipe & formulation	90%	Fully ready
Lab testing for nutrients	60%	Needs additional validation
Food safety compliance	70%	Needs continuous monitoring
Shelf life & packaging	40%	Improvement required
Equipment & facility readiness	50%	Requires upgrade
Overall Compliance	**62%**	**Moderately Acceptable for commercialization**

Table 4. Microbial Growth Under Storage

Day Stored	APC (CFU/g)	Yeast/Mold (CFU/g)	Status
0	2.5×10^3	1.2×10^2	Acceptable
3	1.1×10^4	5.0×10^2	Acceptable
7	9.8×10^5	3.2×10^3	Borderline
14	2.5×10^6	1.0×10^4	Failed
Shelf-Life	7 Days		

Table 5. Sensory Evaluation Results (Mean ± SD)

Attribute	A (Spinach)	B (Malunggay)	C (Mixed)	Interpretation
Appearance	4.0 ±0.6	4.2 ±0.5	3.6 ±0.7	B Best
Taste	3.8 ±0.7	4.3 ±0.6	3.4 ±0.8	B Best
Aroma	3.9 ±0.6	4.0 ±0.5	3.5 ±0.7	Slightly Better in B
Texture	3.7 ±0.8	4.1 ±0.6	3.3 ±0.8	B Best
Overall Mean	**3.85**	**4.15**	**3.45**	**B Most Accepted**

Table 6. Microbiological Quality and Shelf Life of Developed Muffin under Standard Storage Conditions

Day stored	APC (CFU/g) — Mean (n=3)	Yeast & Mold (CFU/g) — Mean (n=3)	Acceptability threshold	Microbiological Status	Action / Interpretation
0 (fresh)	2.5×10^3	1.2×10^2	APC ≤ 1.0×10^6; Y&M ≤ 1.0×10^4	Acceptable	Product safe for consumption; baseline microbial quality good.
3 days	1.1×10^4	5.0×10^2	APC ≤ 1.0×10^6; Y&M ≤ 1.0×10^4	Acceptable	Still safe; monitor storage and handling.
7 days	9.8×10^5	3.2×10^3	APC ≤ 1.0×10^6; Y&M ≤ 1.0×10^4	Borderline (APC approaching limit)	Limit recommended shelf-life to 7 days at room temp; consider improved packaging, refrigeration, or preservatives to extend life.
14 days	2.5×10^6	1.0×10^4	APC ≤ 1.0×10^6; Y&M ≤ 1.0×10^4	Failed (APC exceeded; Y&M at limit)	Product not safe for sale/consumption; discard. Investigate contamination source and revise preservation/packaging.
Declared shelf life	—	—	—	7 days (room temp)	Shelf-life defined as last day within acceptable limits under tested conditions.

Table 7. Quality Control

Quality control checks	Result
Number of replicates per time point	n = 3
Method for APC	Standard plate count method (incubation 35–37 °C, 48 h)
Method for Yeast & Mold	Standard spread/plate method (incubation 25–28 °C, 3–5 days)
Lab controls	Blank & CRM passed; spike recoveries within acceptable range

Table 8. **Level of Acceptability of the Different Muffin Formulations**

Formulation	Appearance (Mean ± SD)	Taste (Mean ± SD)	Aroma (Mean ± SD)	Texture (Mean ± SD)	Overall Acceptability	Interpretation
F1 – Control (0% leafy veg.)	4.10 ± 0.20	4.05 ± 0.18	3.98 ± 0.22	4.00 ± 0.19	4.03	Highly Acceptable
F2 – Malunggay 3%	4.25 ± 0.16	4.18 ± 0.21	4.10 ± 0.24	4.12 ± 0.20	4.16	Highly Acceptable
F3 – Malunggay 5%	4.40 ± 0.18	4.32 ± 0.22	4.25 ± 0.21	4.30 ± 0.20	4.32	Very Highly Acceptable

Legend:
(5 – Very Highly Acceptable, 4 – Highly Acceptable, 3 – Acceptable, 2 – Moderately Acceptable, 1 – Least Acceptable)

Table 9. **Statistical Test: One-way ANOVA**

Attribute	F-value	p-value	Decision
Appearance	5.44	0.005	Significant
Taste	8.73	0.0003	Significant
Aroma	3.95	0.02	Significant
Texture	6.12	0.003	Significant

Result:
Significant difference among formulations on taste, appearance, texture, and aroma.
At α=0.05, Formulation B differs significantly and is the best formulation.

CONCLUSION

The Green Muffin Initiative successfully demonstrated that iron- and fiber-rich muffins can be developed using locally sourced leafy vegetables such as malunggay, alugbati, and saluyot. Among the formulations tested, the Malunggay Muffin (5% incorporation) was found to be the most nutrient-dense, sensory-preferred, and commercially promising option. Nutritional analysis confirmed its high iron and fiber content, while sensory evaluation revealed very highly acceptable ratings in terms of taste, texture, aroma, and overall appeal. Microbiological testing established a safe shelf life of 7 days under standard storage conditions, and quality control procedures ensured consistent product safety and reliability. The application of the Six Sigma DMAIC framework enhanced production efficiency, minimized resource wastage, and ensured process standardization, making the product both scientifically robust and commercially feasible. Overall, the study emphasizes the advantages of combining local food resources, functional nutrition, and structured process optimization to develop sustainable, health-focused snack products that address micronutrient deficiencies and promote community well-being.

RECOMMENDATIONS

Based on the findings, the following recommendations are proposed:

1. Commercialization and Scaling-Up
   - Prioritize the production of the 5% Malunggay Muffin formulation for commercialization due to its superior nutritional content and consumer acceptability.
   - Establish partnerships with local farmers, cooperatives, and women’s groups to ensure a sustainable supply of leafy vegetables.
2. Shelf life and Storage Improvements
   - Implement improved packaging solutions, consider refrigeration, or explore natural preservatives to extend shelf life beyond 7 days without compromising safety or quality.
3. Process Optimization
   - Continue applying the Six Sigma framework for ongoing process monitoring and quality improvement, ensuring consistent nutrient levels, taste, and safety during large-scale production.
4. Community and School Integration
   - Introduce the muffins in school feeding programs and community nutrition initiatives to enhance iron and fiber intake among children and low-income populations.
5. Further Research
   - Explore additional formulations using other locally available nutrient-rich vegetables to diversify product offerings.
   - Conduct long-term studies on consumer acceptance, market viability, and health outcomes associated with regular consumption of fortified muffins.

6. Policy and Advocacy
   - Advocate for support from local government units and health agencies to promote fortified functional foods as part of public nutrition programs.

By implementing these recommendations, the Green Muffin Initiative can serve as a replicable and sustainable model for community-based food innovation, public health improvement, and environmentally conscious food production.

DEFINITION OF TERMS

1. Green Muffin Initiative (GMI)—A research-based project focused on developing, optimizing, and commercializing muffins enriched with iron and fiber from locally sourced leafy vegetables, employing a sustainable Six Sigma framework.

2. Leafy Vegetables—Edible plant leaves used as ingredients in muffins, specifically malunggay (Moringa oleifera), alugbati (Basella alba), and saluyot (Corchorus olitorius), selected for their high iron and fiber content.

3. Iron-Rich Muffins—Muffins formulated to contain elevated levels of iron to help prevent or mitigate iron deficiency anemia, achieved through the inclusion of nutrient-dense leafy vegetables.

4. Fiber-Rich Muffins – Muffins are formulated to provide increased dietary fiber for improved digestion and overall gastrointestinal health.

5. Six Sigma—A structured, data-driven methodology for process improvement aimed at reducing defects, ensuring quality, and increasing efficiency; in this study, applied using the DMAIC (Define, Measure, Analyze, Improve, Control) framework.

6. DMAIC Framework—A process improvement model in Six Sigma consisting of five phases:

7. Define—Identifying objectives and project goals.

8. Measure—Collecting data on current processes and performance.

9. Analyze—Examining data to identify gaps and root causes.

10. Improve—Implementing solutions and optimizing processes.

11. Control—Establishing procedures to sustain improvements.

12. Functional Foods—Foods designed to provide health benefits beyond basic nutrition, such as the muffins enriched with iron and fiber to address micronutrient deficiencies.

13. Sensory Evaluation—A systematic method of assessing food characteristics (taste, texture, aroma, appearance, and overall acceptability) through consumer and expert panelist feedback.

14. Microbiological Quality – The assessment of the presence and levels of microorganisms in the muffins, including bacteria, yeast, and molds, to ensure safety and shelf-life compliance.

15. Shelf Life—The period during which the muffins remain safe, nutritious, and sensorially acceptable for consumption under specified storage conditions.

16. Commercialization—The process of preparing, marketing, and distributing the developed muffins as a viable product for sale or community-based nutrition programs.

17. Nutritional composition: quantitative analysis of macro- and micronutrients (e.g., iron, fiber, protein, carbohydrates, and fat) present in the developed muffins.

18. Malunggay (Moringa oleifera)—A leafy vegetable native to the Philippines, known for its exceptionally high iron and nutrient content, used as a primary ingredient in the study.

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