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Development and Evaluation of Nutrient-Rich Functional Cookies Using Moringa Leaves and Palmyra-Based Ingredients

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Abstract

This study focused on the development and evaluation of nutrient-rich functional cookies using underutilized, cost-effective palmyra-based ingredients and moringa leaves. Moringa (*Moringa oleifera*) leaf powder and palmyra (*Borassus flabellifer*) based ingredients, specifically palmyra sprout flour and jaggery, were incorporated to formulate a healthier alternative to conventional cookies, which are typically high in refined sugar and low in essential nutrients. Cookies were prepared using different ingredient ratios, and the most acceptable formulation was selected through sensory evaluation. The control sample was made of all-purpose flour and palm jaggery. The cookie formulation identified as optimal through sensory evaluation was further analyzed for proximate composition, mineral content, antioxidant capacity, antimicrobial activity, and microbiological safety.The nutritional analysis revealed that the cookies were a rich source of protein (8.46 g/100 g), potassium (201.34 mg/100 g), and calcium (93.15 mg/100 g), a moderate source of iron (0.61 mg/100 g), and provided adequate energy (359.80 kcal/100 g). The antioxidant activity (IC_{50} = 25.63 mg/mL) confirmed the presence of bioactive compounds contributed by moringa leaves and palmyra-based ingredients. Microbiological evaluation, including total plate count (1.2×10^3 cfu/g) and yeast and mould count ($< 1 \times 10^2$ cfu/g) , indicated that the product was safe for consumption and complied with Sri Lanka Standards (SLS 251:2010). Overall, the developed cookies can be considered a palatable, functional, and nutritionally fortified food product, offering a promising healthier snack alternative that may contribute to improved nutrition and help address malnutrition-related health concerns.

Keywords : functional cookies, sensory evaluation, nutritional analysis, bioactive compounds, Microbiological evaluation

1. Introduction

Most people worldwide face a range of health issues, including malnutrition, constipation, osteoporosis, compromised immune function, abdominal discomfort, and cardiovascular diseases. These conditions are largely associated with unhealthy dietary habits, particularly the frequent consumption of junk and fast foods[1]. Such eating patterns are often driven by increasingly busy lifestyles, which limit access to balanced, nutrient-rich meals. Therefore, there is a growing need for convenient and simple food options that provide essential nutrients. Many underutilized food resources available in our country are rich in valuable nutrients; thus, developing a snack product using these ingredients could offer a fast, simple, and cost-effective approach to meeting nutritional requirements and promoting better health.

One of the underutilized food resources is *Moringa oleifera* leaves, which are highly nutritious and contain substantial amounts of calcium, protein, dietary fiber, vitamins A and C, iron, potassium, and essential amino acids[2]. In addition to their rich nutrient composition, moringa leaves serve as a natural source of antioxidants and can be consumed in various forms, including fresh, cooked, or powdered[3]. The nutritional profile of moringa leaves surpasses that of commonly consumed foods such as carrots, milk, spinach, oranges, and bananas[4]. Numerous health

benefits have been associated with moringa leaf consumption, including a reduced risk of cardiovascular diseases, improved glycemic control in diabetes, regulation of blood pressure, enhancement of immune function, improved gut health, and a lowered risk of certain cancers, as well as benefits for skin and hair health [3]

Palmyrah sprout is another underutilized food resource derived from the palmyrah palm (*Borassus flabellifer*), a tree widely distributed across several Asian countries, including Sri Lanka, India, and Indonesia, and known for its medicinal and nutritional value. Palmyrah sprouts are rich in iron, which aids in hemoglobin synthesis and supports immune function. In addition, their low glycemic index helps regulate blood glucose levels [5][6]. The sprouts provide essential nutrients, including vitamins, minerals, and protein, and have been associated with multiple health benefits such as improved bowel movements, reduced cholesterol levels, enhanced bone and dental health, a lowered risk of cardiovascular diseases, and maintenance of a healthy body weight. Furthermore, the protein content of palmyrah sprouts plays a key role in tissue repair and overall body maintenance [5] .

Furthermore, Palmyrah jaggery is considered a healthier alternative to refined sugar derived from sugarcane, as it exhibits a lower glucose-to-fructose ratio and a reduced glycemic index. It is also richer in protein, iron, vitamins B and C, and minerals such as calcium compared to regular sugar [7]. Palmyrah jaggery is produced by boiling palm sap (Neera), followed by filtration and concentration. Notably, it contains a higher proportion of non-reducing sugars relative to reducing sugars, which contributes to its slower metabolic absorption [8]. Considering the high nutritional value of moringa leaves and the health-promoting properties of palmyrah-based ingredients, the major objective of this study was to develop a nutrient-rich functional cookie. This cookie is intended to serve as a convenient and easily accessible snack that provides essential nutrients to support overall health, particularly for individuals with busy lifestyles. Moreover, the use of underutilized, cost-effective ingredients such as moringa leaves and palmyrah products enhances the economic feasibility of the product, making it a practical and beneficial option for regular consumption.

2. Materials and Methods

The present investigation was carried out at the Advanced Research Laboratory of the Department of Science and Technology, Faculty of Applied Sciences, Uva Wellassa University. Cookies were prepared using moringa (*Moringa oleifera*) leaf powder, palmyra (*Borassus flabellifer*) sprout flour, and palmyra jaggery. The materials and methods adopted during the course of the investigation are described below.

2.1 Preparation of Palmyra Flour

Fresh palmyra sprouts were obtained from the Jaffna market. The sprouts were washed thoroughly and boiled with salt for 20–30 minutes. After boiling, they were allowed to cool, and the outer layers and inner stems were removed. The sprouts were then peeled and cut into small pieces. Subsequently, the pieces were drained and sun-dried for 5–7 days. The dried slices were ground using a grinding machine and sieved to obtain fine flour. The flour samples were packed in 300-gauge polyethylene bags, sealed, and labelled for further use.

2.2 Preparation of Moringa Leaves Powder

Fresh, tender *Moringa oleifera* leaves were harvested from the Badulla area. The stems and stalks were removed, and the leaves were washed thoroughly two to three times with clean water. The washed leaves were spread on a kitchen napkin to absorb excess moisture and subsequently placed on a sieve and shade-dried for 2–3 days. The dried leaves were then dry roasted at 50℃ for 3 minutes.

Separately, 20g of white sesame seeds , 2g of pepper, 25g of urad dal, 25g of gram dal, 10 dried red chilies, 8g of tamarind, and 3g of dried curry leaves were dry-roasted at 50℃ for 3 minutes in a pan. 2g of salt was then added. The roasted ingredients were mixed with the dry-roasted moringa leaves and ground using a grinder to obtain a fine powder. The prepared moringa leaf powder was packed in airtight containers and stored for further use.

2.3 Preparation of Nutritious Cookies

The baking oven was preheated to 180 °C prior to cookie preparation. A 20g of Butter and an egg were creamed using a food mixer, after which powdered palm jaggery was gradually incorporated. Palmyra flour and the moringa leaf mixture were then added, and the ingredients were mixed thoroughly to form a uniform dough. The dough was covered and allowed to rest for 10 minutes.

Subsequently, the dough was portioned and shaped into uniformly sized cookies, which were arranged on baking trays. The cookies were baked at 180 °C for 20 minutes until a golden-brown colour was achieved. After baking, the cookies were cooled to room temperature, packed in 400-gauge polyethylene bags, and stored in a cool, dry place.

Table 1 :
Composite ingredient formulations for the development of nutritive cookies from palm jaggery, all-purpose flour, Palmyra sprout flour and Moringa leaves powder respectively.

Sample No	Weight of palm jaggery	Weight of all-purpose flour	Weight of Palmyra Sprout flour	Weight of Moringa powder
1 (control)	20g	50g	-	-
2	20g	42g	6g	2g
3	20g	38g	8g	4g
4	20g	34g	10g	6g
5	20g	30g	12g	8g

2.4 Sensory Analysis

The sensory evaluation of prepared cookies was carried out by a 30 member untrained panel.

The panel members were requested to evaluate the cookies for taste, color, texture, aroma, flavor, and overall acceptability using a 5-point hedonic scale (5 = like extremely, 1 = dislike extremely). Mean scores were calculated, and the accepted sample was selected based on sensory preference.

2.5 Physiochemical Properties of the cookies

2.5.1 Physical Properties of the Cookies

Cookie weight, width, and thickness were measured using a vernier caliper. Five cookies were analyzed, and the average values were calculated. The spread ratio was determined by dividing the average diameter (mm) by the average thickness (mm).

2.5.2 Moisture content (%)

Moisture content was determined by drying 5g weighed sample at 105 °C to constant weight in the oven. The loss in mass (percentage basis) was calculated by using the following equation.

$$\text{Moisture content (\%)} = \frac{W2-W3}{W2-W1} \times 100 \quad (1)$$

Here, W1 represents the weight of the empty dish, W2 denotes the combined weight of the dish and the sample before drying, and W3 indicates the combined weight of the dish and the sample after drying.

2.5.3 pH level

pH meter was calibrated with pure water (pH = 7), acidic solution (pH = 4), and base solution (pH = 10). A sample solution was made by dissolving 5 g of the sample in distilled water. pH was determined by dipping the pH meter into sample solution.

2.5.4 Total ash content

The 5g of the sample was measured. It was charred and, ashed at 550 °C in a muffle furnace, and the weight difference before and after ashing was calculated by following equation.

$$\text{Total ash content (\%)} = \frac{W2-W}{W1-W} \times 100 \quad (2)$$

Here, W_1 represents the weight of the crucible and the sample, W_2 denotes the weight of the crucible alone, and W refers to the weight of the crucible together with the dried sample.

2.5.5 Fat content

Fat content was measured by the Soxhlet extraction method. The dried extraction flask was weighed, and 5.0 g of oven-dried sample was placed in a paper thimble and it was extracted with 75.0 mL of petroleum ether at 150 °C for 6 hours. After extraction, the flask with oil was oven dried, cooled in a desiccator. The fat content was calculated by following the equation.

$$\text{Fat content (\%)} = \frac{W1-W2}{W3} - 100 \quad (3)$$

Here, W_1 represents the weight (g) of the empty extraction beaker, W_2 denotes the weight (g) of the low-fat desiccated sample, and W_3 indicates the final weight (g) of the beaker together with the extracted oil.

2.5.6 Protein content

Protein content was analyzed using the Kjeldahl method through digestion, distillation, titration, and calculation of nitrogen content. About 1 g of powdered sample was digested with concentrated sulfuric acid and a catalyst at 420 °C until clear, then diluted with distilled water. The digest was neutralized, and the released ammonia was distilled into boric acid with indicator and titrated with 0.1 N hydrochloric acid to calculate crude protein.

2.5.7 Calcium content

The ash sample was dissolved in nitric acid by heating, filtered, and diluted to 50 mL with distilled water, from which 10 mL was taken for analysis. Potassium

hydroxide, potassium cyanide, hydroxylamine, and Patton & Reeder indicator were added, and the solution was titrated with 0.0025 M EDTA. Color change was observed as follows. pink → purple → Blue(result)

2.5.8 Antioxidant activity

Antioxidant activity was determined using the DPPH radical scavenging assay following Huang et al. (2005). A 0.1 mL sample extract was mixed with 3.9 mL of 0.15 mM DPPH solution, it was incubated in the dark for 30 minutes, and absorbance was measured at 515 nm against a methanol blank, with all analyses performed in triplicate. The DPPH scavenging was determined using the following formula.

$$\text{Antioxidant activity (\%)} = \frac{\text{Abs (t=0) - Abs (t=30)}}{\text{Abs (t=0)}} \quad (4)$$

Here, Abs (t = 0) represents the absorbance of the DPPH radical in methanol at 0 minutes, while Abs (t = 30) denotes the absorbance of the DPPH radical in the presence of phenolic extracts at 30 minutes.

2.5.9 Potassium level

Potassium was determined by a gravimetric method using sodium tetraphenylborate (TPB). A potassium chloride solution was acidified, precipitated with sodium TPB under controlled temperature, allowed to settle, then filtered, washed, and dried to constant weight. The precipitate was weighed for potassium estimation, and the TPB reagent was later recovered and recrystallized for reuse.

2.5.10 Iron content

Iron content was determined by a colorimetric method in which the sample was acid-digested, reduced to ferrous iron using hydroxylamine hydrochloride, and reacted with o-phenanthroline to form a colored complex. The absorbance was measured at about 510 nm using a spectrophotometer, and iron concentration was calculated from a standard calibration curve.

2.5.11 Energy content

Energy content of was determined using a bomb calorimeter. About 1 g of sample was combusted in an oxygen-filled sealed bomb using electrical ignition, and the resulting temperature rise was recorded to calculate the energy value.

2.5.12 Antimicrobial Activity

Total Plate Count: Peptone water and plate count agar were prepared and sterilized by autoclaving at 121 °C for 15 minutes. An initial extract was prepared by homogenizing 10 g of cookie in 90 mL buffered peptone water, followed by serial dilutions, which were plated on plate count agar and incubated at 30 °C for 48 hours. Colonies within 30–300 CFU were counted to calculate microbial load using the standard formula.

$$N = \frac{\sum C}{(n1+0.1n2)d} \quad (5)$$

Here, N represents the number of colonies per gram, C denotes the sum of colonies counted on all retained dishes, n_1 refers to the number of dishes retained in the first dilution, n_2 indicates the number of dishes retained in the second dilution, and d is the dilution factor corresponding to the first dilution.

Yeast and mould test: Peptone water, DRBC, and DG18 media were prepared by dissolving measured reagents in distilled water, stirred, and sterilized at 121 °C. Ten grams of sample was homogenized in 90 mL peptone water, serially diluted, and 0.1 mL of each dilution was plated on DRBC or DG18 plates, spread evenly, and incubated at 25 °C for 5–7 days. Colonies on plates with 15–150 CFU were counted using a colony counter, and results were calculated by using the same standard equation above.

3. Results and Discussion

3.1 Sensory analysis

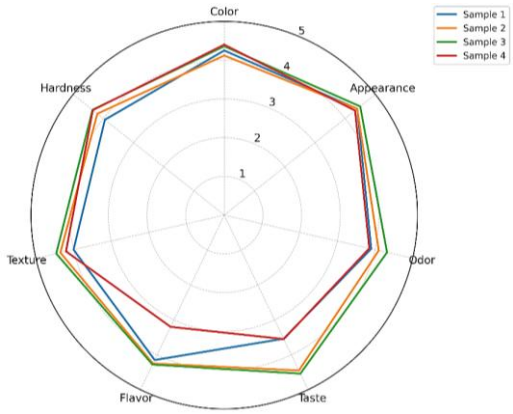

Fig. 1 : Web diagram for sensory test

Based on the Friedman test results, no statistically significant differences were observed among the five cookie samples for the evaluated sensory attributes ($P > 0.05$; Figure 03). This indicates that sensory analysis did not show a statistically significant preference among the samples. However, descriptive analysis using the web (radar) diagram (Figure 01) revealed that Sample 3 (Figure 02) consistently

obtained higher mean scores across most key sensory attributes, indicating better overall sensory performance. In contrast, Samples 1 and 4 showed comparatively lower scores, particularly for taste and flavor. Therefore, based on descriptive sensory trends, Sample 3 (38 g all-purpose flour, 8 g palmyra sprout flour, 20 g palmyra jaggery, and 4 g moringa powder) was selected as the most acceptable formulation for further consideration.

Fig. 2. Most accepted cookies in sensory test.

Descriptive Statistics

Attribute	N	Median	Sum of Ranks
Appearance	5	4.33000	30.0
Color	5	4.21143	26.5
Flavor	5	3.90000	13.0
Hardness	5	4.10857	22.5
Odor	5	3.92571	12.0
Taste	5	3.68714	18.0
Texture	5	4.04714	18.0
Overall	35	4.03000	

Test

Null hypothesis	H_0: All treatment effects are zero
Alternative hypothesis	H_1: Not all treatment effects are zero

Method	DF	Chi-Square	P-Value
Not adjusted for ties	6	11.55	0.073
Adjusted for ties	6	11.59	0.072

Fig. 3. Friedman test results of the sensory analysis

3.2 Physiochemical Properties of the cookies

3.2.1 Physical Properties of the Cookies

The physical evaluation showed a cookie weight of ±27 g, diameter of ±37.42 mm, thickness of ±14.26 mm, and a spread ratio of ±2.67, indicating limited spread due to water-absorbing ingredients.

3.2.2 Moisture content

The moisture content of the developed cookies was 6.02 g/100 g, which is within the recommended maximum level of 10% for baked products. Maintaining a low moisture content is essential for extending shelf life, as it limits microbial growth and reduces the risk of spoilage. In addition, the low moisture level contributes to the desirable crisp texture and brittleness of cookies, which are important quality attributes for consumer acceptability. Therefore, the moisture content of the developed cookies indicates good product stability and textural quality.

3.3.3 Total Ash Content

Ash content is an important nutritional quality parameter, as it reflects the presence of essential minerals such as calcium, potassium, magnesium, iron, and zinc, which contribute to the functional value of food products. The total ash content of the developed cookies was 2.32 g/100 g (Table 02), which falls within acceptable limits, as the average ash content of cookies is generally expected to be less than 3% according to standard cookie flour quality. The observed ash content indicates that the developed cookies provide a considerable amount of essential minerals while maintaining acceptable quality standards. This may be attributed to the incorporation of mineral-rich raw materials such as palmyra sprout flour, palmyra jaggery, and moringa leaf powder. Similar findings were reported who observed higher ash content in jaggery-based cookies due to the naturally high mineral content of jaggery [9].

3.3.4 pH level

The pH of cookies generally ranges between 6.5 and 7.5 and should not exceed 9, depending on the formulation and processing conditions. The pH of the developed cookies was 6.62, indicating a slightly acidic to near-neutral nature. The pH of standard cookies typically falls between 6.0 and 7.0, which is consistent with the value observed in the present study [10]. A pH within this range is considered desirable for cookie quality, as it supports optimal flavor and texture development by regulating the Maillard reaction during baking, a key process responsible for desirable color and flavor formation [11]. From a microbiological perspective, cookies generally exhibit low water activity; therefore, pH plays a secondary role in spoilage. A pH around 6.6 may contribute to improved shelf stability by limiting the growth of certain acid-sensitive microorganisms [10]. Overall, the obtained pH value supports desirable baking characteristics, product quality, and food safety.

3.3.5 Fat content

Fat plays a crucial role in cookie quality, as it interferes with gluten network formation during mixing, leading to a more tender and crumbly texture while also

facilitating cookie spread during baking [11]. Fat also acts as a carrier of fat-soluble flavour compounds, enhancing mouthfeel and overall palatability [12].

The fat content of the developed cookies was measured at 14.22 g/100 g. This level of fat contributes to desirable texture and sensory characteristics without being excessively high. From a nutritional perspective, moderate fat content helps develop a tender crumb and improves sensory attributes such as taste and mouthfeel. Studies have shown that reducing fat content below moderate levels often results in cookies that are harder and less acceptable in texture unless appropriate fat replacers are incorporated [13]. Fat also contributes to the creaming process, which improves dough aeration, spread, and final volume; it aids moisture retention and may contribute to extended shelf life in baked products [14].

3.3.6 Protein

The protein level was determined as 8.46g/100g. It is important for the structure, quality and nutrition of the cookie. Protein enhances nutritional value by providing essential amino acids required for body maintenance and growth. This adequate protein level intake enhances satiety, and control appetite. The protein content of 8.46g/100g adds more nutritional value to cookies, thus making it more than an energy source from carbohydrates and fats. This sufficient level supports muscle growth and repair and making the cookie a minor source of dietary protein.

Moringa leaves have many valuable compounds such as protein, vitamins, calcium, iron, folic acid, and antioxidants (carotenoids, flavonoids, and phenols) [15]. Dried leaves of Moringa contained high amounts of protein and crude fibers which were 26.79 and 18.67 %, respectively [16]. The combination of moringa leaf powder has increased the nutritional value and the contribution of macro and micronutrients, including protein, fibre, vitamins, and minerals which is reported by [17] .

3.3.7 Effect of Calcium

The calcium content of the developed cookies was 93.15 mg/100 g, indicating a significantly higher mineral value compared to conventional cookies. Calcium is an essential mineral required for the development and maintenance of healthy bones and teeth and plays a vital role in several physiological processes, including muscle contraction, nerve impulse transmission, regulation of cardiac function, and blood clotting [18]. Adequate calcium intake is also important for the prevention of bone-related disorders such as osteoporosis and rickets. Although the calcium content of the developed cookies does not meet the full daily recommended intake for adults (approximately 800–1000 mg/day) [19], the observed level is considerably higher than that of conventional cookies, which typically contain only 8–38 mg/100 g. Therefore, the developed cookies can serve as a supplementary dietary source of calcium, particularly for individuals with limited intake of calcium-rich foods. Furthermore, the enhanced mineral content may contribute to improved overall nutritional quality, as the presence of essential minerals and vitamins has been reported to support immune function and general health [20] .

3.3.8 Potassium Content

The potassium content of the developed cookies was determined to be 201.34 mg/100 g, indicating that they provide a significant contribution to daily potassium intake and enhance overall nutritional quality. Potassium is a major intracellular cation involved in maintaining membrane potential, supporting electrical excitability of nerve and muscle cells, and regulating acid-base balance through renal function[21] . The observed potassium level suggests that the cookies can serve as a moderate dietary source of this essential mineral, particularly when compared to conventional cookies, which generally contain lower potassium levels. This enhancement is attributable to the incorporation of mineral-rich ingredients such as moringa leaf powder, palmyra sprout flour, and palmyra jaggery. Palm jaggery, in particular, is naturally rich in potassium and other minerals, which may also provide additional health benefits, including supporting weight management [22].

3.3.9 Iron content

The iron content of the developed cookies was 0.61 mg/100 g (Table 02). Iron is essential for hemoglobin and myoglobin synthesis, supporting oxygen transport, energy metabolism, cognitive function, and immune defense [23]. Although this level is low to serve as a primary source, it enhances the nutritional value compared to conventional cookies, which generally contain less iron. The iron is contributed by moringa leaf powder, palmyra sprout flour, and palmyra jaggery, the latter being a good source of both iron and magnesium. While the cookies alone cannot prevent iron deficiency, they can act as a supplementary source of iron within a balanced diet. Previous studies have shown that cookies fortified with moringa leaf powder can help increase hemoglobin levels and prevent anemia, particularly in pregnant women [24].

3.3.10 Antioxidant activity

The antioxidant activity of the developed cookies, measured by the DPPH assay, showed an IC_{50} value of 25.63 mg/mL (Table 02), indicating moderate free radical

scavenging capacity. Lower IC_{50} values indicate stronger activity, with compounds like ascorbic acid typically showing values below 5 mg/mL [25] [26]. The inclusion of moringa leaf powder and palmyra jaggery enhanced the cookies' nutritional and antioxidant properties. Moringa leaves are known for high antioxidant activity [27], while jaggery has higher total phenolic content than refined sugar, contributing to improved radical scavenging and protection against oxidative damage [28]. Overall, the combination of these ingredients contributed to the moderate antioxidant activity of the cookies, enhancing their functional and nutritional value.

3.3.11 Energy Content

The energy content of the developed cookies was 359.80 kcal/100 g (Table 02), indicating a moderate caloric value among common bakery products. Cookies generally fall within the range of 350–500 kcal/100 g, depending on formulation [10] . The energy level of this sample is consistent with standard commercial cookies and provides a convenient source of calories, making it suitable as a snack to meet immediate energy needs. This caloric content also allows the cookies to be incorporated safely into a balanced diet.

Table 2 :
Nutritional Profile Analysis Results of the selected cookie

Nutritional Parameters	Results
Moisture Content	6.02g/100g
Total Ash Content	2.54g/100g
pH	6.62
Fat Content	14.22g/100g
Protein	8.46g/100g
Calcium	93.15mg/100g
Potassium	201.34mg/100g
Iron	0.61mg/100g
IC50	25.63mg/mL
Energy	359.80kcal/100g

3.3.12 Microbiological Analysis

Total Plate Count: The average total plate count of the five cookie samples was 1.2×10^3 cfu/g, which is below the safety limits specified by SLS 251:2010 (lower limit = 1×10^3 cfu/g, Upper limit = 1×10^4 cfu/g). Since the values are at the threshold of the acceptable lower limit (m), the results indicate that the cookies are microbiologically safe and demonstrate good hygienic quality. These findings reflect effective processing, proper handling, and minimal contamination during production. Comparable total plate counts have been reported in cookies fortified with plant-based ingredients, where values ranged from 10^2 to 10^3 cfu/g, indicating acceptable microbiological quality [29]. The low total plate count observed in the present study suggests that the developed cookies are unlikely to pose health risks to consumers and supports their safe shelf life under recommended storage conditions.

Yeast and Mould count: The yeast and mould counts in all five cookie samples were $< 1 \times 10^2$ cfu/g, which falls well within acceptable microbiological limits for bakery products (1.2×10^2 to 1.2×10^3 cfu/g). This indicates excellent microbiological safety with respect to fungal contamination. Low yeast and mould counts suggest that the cookies are

resistant to spoilage and were prepared, processed, and stored under good hygienic conditions. Similar low yeast and mould counts have been reported in cookies fortified with plant-based ingredients, including moringa leaf powder and cereal-based composite flours, where values remained below 10^2–10^3 cfu/g, indicating good microbial stability [29]; Since yeast and mould growth can adversely affect sensory quality and shelf life, the present results confirm that the developed cookies maintain stable quality with minimal risk of fungal spoilage. The low fungal counts also correlate with the low moisture content (6.02 g/100 g), which further limits fungal proliferation and supports extended shelf life.

4. Conclusion

The study successfully developed nutritious cookies using Moringa leaves and Palmyra-based ingredients. The findings demonstrate that the formulated cookies contain elevated levels of protein, minerals, energy, and antioxidants while maintaining consumer acceptability. Their low moisture content and favorable pH contribute to product stability and extended shelf life, and microbial analyses confirmed that all counts are within safe limits, ensuring the cookies are safe for consumption. These cookies not only address malnutrition and nutrient deficiencies but also promote the valorization of locally available, underutilized agricultural resources such as Moringa and Palmyra, adding economic value to these crops. Overall, the developed cookies can be recommended as a functional, value-added, cost-effective, and health-promoting snack suitable for all age groups.

References

[1] Townsend JR, Kirby TO, Marshall TM, Church DD, Jajtner AR, Esposito R. Foundational Nutrition: Implications for Human Health. Nutrients. 2023 Jun 22;15(13):2837. doi: 10.3390/nu15132837. PMID: 37447166; PMCID: PMC10343467.

[2] Moyo, B., Masika, P. J., Hugo, A., & Muchenje, V. (2011). Nutritional characterization of Moringa (Moringa oleifera Lam.) leaves. African Journal of Biotechnology, 10(60), 12925–12933.

[3] Fahey, J. (2005): *Moringa oleifera*: A Review of the Medical Evidence for Its Nutritional, Therapeutic, and Prophylactic Properties. Part 1. Trees for Life Journal. 1:5

[4] *International Journal Of Phytotherapy Research Original Research Article* potential uses of *Moringa oleifera* and an examination of antibiotic efficacy conferred by m. oleifera seed and leaf extracts using crude extraction techniques available to underserved indigenous populations. (2013). [online] Academia.edu. Available at: https://www.academia.edu/download/32439897/ijpr_136.pdf.

[5] Ebscohost.com. (2026). *Results - OpenURL Connection - EBSCO*. [online] Available at: https://search.ebscohost.com/login.aspx

[6] Krishnaveni, T.R.S., Arunachalam, R., Chandrakumar, M., Parthasarathi, G. and Nisha, R. (2020). Potential Review on Palmyra (Borassus flabellifer L.). *Advances in Research*, 21(9), pp.29–40. doi: https://doi.org/10.9734/air/2020/v21i930229

[7] Upadhyaya, A. and Sonawane, S.K. (2023). Palmyrah palm and its products (Neera, Jaggery and Candy)—A Review on chemistry and technology. *Applied Food Research*, [online] 3(1), p.100256.doi:https://doi.org/10.1016/j.afres.2022.100256

[8] Lamdande, A.G., Khabeer, S.T., Kulathooran, R. and Dasappa, I., 2018. Effect of replacement of sugar with jaggery on pasting properties of wheat flour, physico-sensory and storage characteristics of muffins. *Journal of food science and technology*, *55*(8), pp.3144-3153.

[9] Mahalaxmi, B.K. and Hemalatha, S., 2018. Functional and nutritional characteristics of organic jaggery millet cookies. *International Journal of Food Science and Nutrition*, *3*(5), pp.171-177.

[10] Autor: D J R Manley (2011). *Manley's technology of biscuits, crackers and cookies*. Editorial: Cambridge: Woodhead Publishing.

[11] Pyler, E. and Gorton, L. (n.d.). *Baking Science & Technology, 4 th edition,Volume1: Fundamentals and Ingredients*. [online] Available at: http://files.wageningenacademic.com/qas_back/j.1757-837X.2009.00023.x.pdf

[12] Nadeem, B., Bacha, R. and Gilani, S.A., 2018. Correlation of subcutaneous fat measured on ultrasound with body mass index. *Journal of medical ultrasound*, *26*(4), pp.205-209.

[13] Sudha, M.L., Srivastava, A.K., Vetrimani, R. and Leelavathi, K. (2007). Fat replacement in soft dough biscuits: Its implications on dough rheology and biscuit quality. *Journal of Food Engineering*, 80(3), pp.922–930. doi: https://doi.org/10.1016/j.jfoodeng.2006.08.006

[14] Ashwath Kumar, K., & Sudha, M. L. (2020). Effect of fat and sugar replacement on rheological, textural and nutritional characteristics of multigrain cookies. Journal of Food Science and Technology, 58(7), 2630–2640.

[15] Anwar, F., Latif, S., Ashraf, M. and Gilani, A.H. (2006). Moringa oleifera: a food plant with multiple medicinal uses. *Phytotherapy Research*, [online] 21(1), pp.17–25. doi: https://doi.org/10.1002/ptr.2023.

[16] El-Massry, F.H., MOSSA, M.E. and YOUSSEF, S.M., 2013. Moringa oleifera plant. *Egyptian Journal of Agricultural Research*, *91*(4), pp.1597-1909.

[17] Milla, P.G., Peñalver, R. and Nieto, G. (2021). Health Benefits of Uses and Applications of Moringa oleifera in Bakery Products. *Plants*, 10(2),p.318. doi: https://doi.org/10.3390/plants10020318.

[18] Gupta, P. and Badami, S. (2024). Multiple Roles of Calcium in Maintaining Human Health. [online] doi: https://doi.org/10.31579/2834-8761/042

[19] National Institutes of Health, Office of Dietary Supplements. (2025). Calcium: Fact sheet for health professionals. U.S. Department of Health and Human Services. https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/

[20]

[21] Busani M, Patrick JM, Arnold H, et al.:Nutritional characterization of Moringa (*Moringa oleifera* Lam) leaves. Afr. J. Biotechnol. 2011; 10(60): 12925–12933.

[22]

[23] Lanham-New, S.A., Lambert, H. and Frassetto, L. (2012). Potassium. *Advances in Nutrition*, [online] 3(6), pp.820–821. doi: https://doi.org/10.3945/an.112.003012

[24] Bandodkar, B. and Mandal', V. (2021). *Vidya Prasarak Mandal's Proceeding of the National Online Conference on Advances in Chemical Sciences and Sustainable Development (ACSSD-2021)*. [online] Available at:

http://www.vpmthane.org/bnb/Proceeding/ACSSD-2021 pdf#page=106 [Accessed 23 Jan. 2026].

[25] Zimmermann, M. B., & Hurrell, R. F. (2020). Nutritional iron deficiency. The Lancet, 397(10270), 233–248. https://doi.org/10.1016/S0140-6736(20)31368-6

[26] Ariani, L.N., Estiasih, T., Sunarharum, W.B. and Khatib, A. (2023). Potential of moringa (Moringa oleifera) leaf powder for functional food ingredients: A review. *Czech Journal of Food Sciences*. doi: https://doi.org/10.17221/221/2022-cjfs

[27] Mochamad Faliq (2015). *Molineux 07-DPPH*. [online] Academia.edu. Available at: https://www.academia.edu/download/39013361/Molineux_07-DPPH.pdf.

[28] Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M. and Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine*, 26(9-10), pp.1231–1237. doi: https://doi.org/10.1016/s0891-5849(98)00315-3

[29] Suphachai, C. (2014). Antioxidant and anticancer activities of Moringa oleifera leaves. *Journal of Medicinal Plants Research*, 8(7), pp.318–325. doi: https://doi.org/10.5897/jmpr2013.5353

[30] Sharifi-Rad, J., Painuli, S., Sener, B., Kılıç, M., Kumar, N.V.A., Semwal, P., Docea, A.O., Suleria, H.A.R. and Calina, D. (2023). Revisiting the nutraceutical profile, chemical composition, and health benefits of jaggery: Updates from recent decade. *eFood*, 4(2). doi: https://doi.org/10.1002/efd2.75

[31] Dachana, k.b., Rajiv, j., Indrani, d. And Prakash, j. (2010). Effect of dried moringa (moringa oleifera lam) leaves on rheological, microstructural, nutritional, textural and organoleptic characteristics of cookies. *Journal of Food Quality*, [online] 33(5), pp.660–677. doi: https://doi.org/10.1111/j.1745-4557.2010.00346.x

[32] Mouminah, H.H.S., 2015. Effect of dried *Moringa oleifera* leaves on the nutritional and organoleptic characteristics of cookies. *Alexandria science exchange journal*, *36*(OCTOBER-DECEMBER), pp.297-302.

[33] Razzak, A., 2021. Effect of drying condition on physicochemical and antioxidant properties of dried moringa leaf powder. *Food Research*.

[34] Riaz, A. and Wahab, S., 2021. Efficacy of Moringa Leaves Powder as a Supplement in Whole Wheat Flour Biscuit. *Sarhad Journal of Agriculture*, *37*.

[35] Ariani, L.N., Estiasih, T., Sunarharum, W.B. and Khatib, A., 2023. Potential of moringa (*Moringa oleifera*) leaf powder for functional food ingredients: A review. *Czech Journal of Food Sciences*, *41*(1).

[36] Abdel-Samie, M.A. and Abdulla, G., 2014. Effect of Moringa leaves (*Moringa oleifera* Lam.) on some physico-chemical and sensory properties of wheat flour cookies. *Zagazig J. Agric. Res*, *41*(2), pp.305-314.

[37] Fahey JW: *Moringa oleifera*: a review of the medical evidence for its nutritional, therapeutic and prophylactic properties. Part 1. Trees for Life Journal. 2005; 1(5): 1–15.

[38] Nwakalor, C.N., 2014. Sensory evaluation of cookies produced from different blends of wheat and *Moringa oleifera* leaf flour. *International Journal of Nutrition and Food Sciences*, *3*(4), pp.307-310.

[39] Wahyuni, R., Wignyanto, W., Wijana, S. and Sucipto, S., 2021. Optimization of foam mat drying process of moringa leaf powder (*Moringa oleifera*) as protein and amino acids sources. *Food Research*, *5*(2), pp.418-426.

[40] Khatri, R.M., Siddiqui, S., Nagamaniammai, G. and Athmaselvi, K.A., 2020. Development of Muffin Using Palmyra (*Borassus flabellifer*) Sprout Flour. *International Journal of Nutrition, Pharmacology, Neurological Diseases*, *10*(1), pp.14-20.

[41] Jerry, A., 2018. A *comprehensive review on the medicinal properties of Borassus flabellifer*. *Journal of Academia and Industrial Research*, *7*(7), pp.93-97.

[42] Thuraisingam, S., Sangeetha, S. and Sithara, K., Influence of different processing and drying approaches in the preparation of palmyrah tuber flour utilized as raw material in food industries.

[43] Dharani Shree, K. and Mythili, T., 2023. therapeutic antidiabetic biscuit–an effective functional food; 1385-1387

[44] Thabrew MI, Jansz ER. Nutritive importance of palmyrah products. Recent Research Developments in Environ Biol 2004;1:43-60.

[45] Upadhyaya, A. and Sonawane, S.K., 2023. Palmyrah palm and its products (Neera, Jaggery and candy)—a review on chemistry and technology. *Applied Food Research*, *3*(1), p.100256.

[46] Upadhyaya, A., Bhalerao, P.P., Bhushette, P., Dabade, A. and Sonawane, S.K., 2023. Optimization study of palm jaggery and palm candy-production and process. *Applied Food Research*, *3*(1), p.100269.

[47] Karuppasamy, P. and Latha, M.R., 2020. Technology assessment on alternative natural sweetener used for cookies through on farm trial (2019-2020); 264-266

[48] KUMAR, R., Development of gluten free cookies using quality protein maize flour and jaggery; 16-28

[49] Manisha, J., Roja, T., Saipriya, S., Jayaprakash, R., Rajender, G. and Swamy, R., 2022. Development of palm jaggery and comparison with sugarcane jaggery. *Pharma Innov. J*, *11*, pp.812-816.

[50] Bolang, A.S.L., Rizal, M., Nurkolis, F., Mayulu, N., Taslim, N.A., Radu, S., Samtiya, M., Assa, Y.A., Herlambang, H.A., Pondagitan, A.S. and Vivo, C.D., 2023. Cookies rich in iron (Fe), folic acid, cobalamin (vitamin B12), and antioxidants: a novel functional food potential for adolescent with anemia. *F1000Research*, *10*, p.1075.

[51] Gaines, C.S., 1986. Baking quality of cookie flour—Micro-method 10-52. *Cereal Foods World*, *31*(1), pp.66-70.

[52] TR Krishnaveni, R Arunachalam, M Chandrakumar, G Parthasarathi, R Nisha Potential review on palmyra (*Borassus Flabellifer L.*) Advances in Research, 2020; 21(9): 29-40.

[53] R. Ravi Kiran, B et al., Statistical analysis of mechanical properties of Kenaf fibre/ Palmyra sprout/Glass fibre reinforced Epoxy composites using Taguchi method International Research Journal of Engineering and Technology, Mar, 2019; 06(03). ISSN: 23950056. www.irjet.net p-ISSN: 2395-0072

[54] Khawaja, T.; Tahira, M. and Ikram, U. (2010): *Moringa oleifera*: a natural gift - A review. J Pharm Sci Res, 2, 775-781.

[55] El - Massry, f.; Mossa, M. and Youssef, S. (2013) : *Moringa Oleifera* Plant Value and Utilization in Food Processing. Egypt. J. Agric. Res., 91 (4).

[56] Vengaiah PC, Ravindrababu D, Murthy GN, Prasad KR. Jaggery from Palmyrah palm (*Borassus flabellifer L.*) Present status and scope, 2013.

[57] Alakali, J., Kucha, C. and Rabiu, I. (2015). Effect of drying temperature on the nutritional quality of *Moringa oleifera* leaves. African Journal of Food Science, 9(7), 395-399.

[58] Chaudhary, K. and Chaurasia, S. (2017). Nutraceutical properties of *Moringa oleifera*: a review. European Journal of Pharmaceutical and Medical Research, 4 (4), 646-655

[59] Rockwood, J.L, Anderson B.G., and Casamatta,D.A. (2013). Potential uses of Moringa oleifera and an examination of antibiotic efficacy conferred by Moringa oleifera leaf and seed extract using crude extraction technique available to underserved indigenous population. International Journal of Phytotherapy Research, 3 (2), pp.61-71.

[60] Rao, M. C. S., Swami, D. V., Ashok, P., Nanda, S. P., & Rao, B. B. (2021). Scope, nutritional importance and value addition in palmyrah (Borassus flabellifer L.): An under exploited crop. In Bioactive Compounds-Biosynthesis, Characterization and Applications. IntechOpen.

[61] Krishnaveni, T. S., Arunachalam, R., Chandrakumar, M., Parthasarathi, G., & Nisha, R. (2020). Potential review on palmyra (Borassus flabellifer L.). Advances in Research, 21(9), 29-40.

[62] Upadhyaya, A., Bhalerao, P. P., Bhushette, P., Dabade, A., & Sonawane, S. K. (2023). Optimization study of palm jaggery and palm candy-production and process. Applied Food Research, 3(1), 100269.

[63] Manual of Analysis of the PAI. (n.d.). *Determination of Ashes* (Cookie Flour Quality Reference). Retrieved from https://www.scribd.com/document/922297600/Determination-of-Ashes Scribd

[64] Chukwu, O., Okechukwu, P., & Okoye, C. (2021). Nutritional and sensory evaluation of composite flour cookies enriched with plantain and tigernut flour. International Journal of Food Science and Nutrition, 6(4), 441–447.

[65] Sudha, M. L., Vetrimani, R., & Leelavathi, K. (2007). Influence of fibre from different cereals on the rheological characteristics of wheat flour dough and on biscuit quality. Food Chemistry, 100(4), 1365–1370. https://doi.org/10.1016/j.foodchem.2005.12.013