Formulation and Evaluation of Chocolate-Coated Millet Balls: A Sustainable, Functional Snack for Consumers

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Abstract

This study aimed to identify the optimal combination of chocolate-coated millet balls that enhances both nutritional and sensory value. Various formulations incorporating sorghum, finger millet, and kodo millet were tested alongside date paste and chopped peanuts. Through extensive sensory evaluations and nutritional analysis, the blend containing 40% millets, 40% date paste, and 20% chopped peanuts emerged as the most balanced and acceptable option. Millets balls were prepared with chosen ratios (40% millets, 40% date paste, and 20% chopped peanuts) and coated with chocolate, such as sorghum (T1), finger millet (T2), and kodo millet (T3), and control formulation (T4). A control treatment comprising 60% chopped peanuts and 40% date paste was used for baseline comparison, but lacked the same nutritional and sensory balance. These formulations demonstrated superior performance in terms of healthy fats, dietary fibre, and essential minerals. Moisture content, ash content, fibre levels, and mineral composition further validated its nutritional quality. Among the millet types, the chocolate-coated kodo millet ball (T3) received the highest sensory ratings, offering a well-rounded and appealing profile. Sorghum and finger millet variants also showed promise, though minor improvements in flavour and aroma were recommended. Overall, the findings suggest that combining millets with date paste and chopped peanuts produces a nutritious and enjoyable snack, with kodo millet standing out as the most favourable base. This formulation holds potential for health-conscious consumers seeking functional and culturally resonant snack options.

Keywords: Chocolate-coated millet balls, Date paste, Finger millet, Kodo millet, Sorghum millet.

Introduction

In the evolving landscape of nutrition and culinary innovation, the integration of ancient grains, natural sweeteners, and indulgent flavours presents a promising opportunity for healthier food development. Millets, cultivated widely across Asia and Africa, are climate-resilient grains recognized for their rich nutritional profile, including dietary fibre, proteins, essential fatty acids, and vital minerals. Their ability to thrive in dry zones and their low glycemic index make them particularly suitable for individuals managing diabetes and other metabolic conditions. Despite these benefits, millets remain underutilized due to limited consumer awareness, processing challenges, and cultural food preferences. Addressing these barriers requires both educational outreach and innovative product development.

Chocolate, while globally beloved, is often criticized for its high sugar and fat content, which contributes to obesity, diabetes, and cardiovascular diseases. Issues such as contamination and chocolate blooming also compromise product safety and shelf appeal. However, when paired thoughtfully with nutrient-dense ingredients, chocolate can be transformed into a balanced snack option. Dates, rich in fibre, vitamins, and minerals, serve as a natural sweetener and healthier alternative to refined sugar, while peanuts provide protein and healthy fats. Together, these ingredients offer a synergistic blend of nutrition, flavour, and cultural relevance.

This study aims to develop chocolate-coated millet balls that harmonise taste, nutrition, and safety. By combining millets with date paste and chopped peanuts, the formulation seeks to enhance dietary value while remaining gluten-free and suitable for diverse dietary needs. The research focuses on formulating millet balls, evaluating their sensory qualities, and analysing their nutritional properties. Through this approach, the study contributes to the growing demand for functional snacks and promotes the wider use of millets in the food industry, offering a product that balances consumer taste preferences with improved nutritional outcomes.

Materials and Methods

Study location

This study was conducted at the Food Technology Laboratory, University College Jaffna.

Raw materials

Millets (kodo, finger, sorghum) were sourced from Pallulei industry, while dates, peanuts, cocoa powder, margarine, sugar, milk, and milk powder were purchased locally. Samples were selected using a random sampling method.

Formulations of Millet Balls

Table 1: Recipe of Millet Formulations

Raw materials & ingredients	**Formulation 1 (T1)**	**Formulation 2 (T2)**	**Formulation 3 (T3)**	**Control (T4)**
Sorghum millet	40%	-	-	-
Finger millet	-	40%	-	-
Kodo millet	-	-	40%	-
Date paste	40%	40%	40%	40%
Peanut	20%	20%	20%	60%

Formulations of Chocolate Ganache

Table 2: Recipe of Chocolate ganache for coating of all formulations

Raw materials & ingredients	**Percentage**
Cocoa powder	6.97%
Sugar	20.91%
Milk powder	10.46%
Milk	13.94%
Margarine	23.13%
Milkmaid	24.1%
Soy lecithin	0.5%

Processing Flow Chart

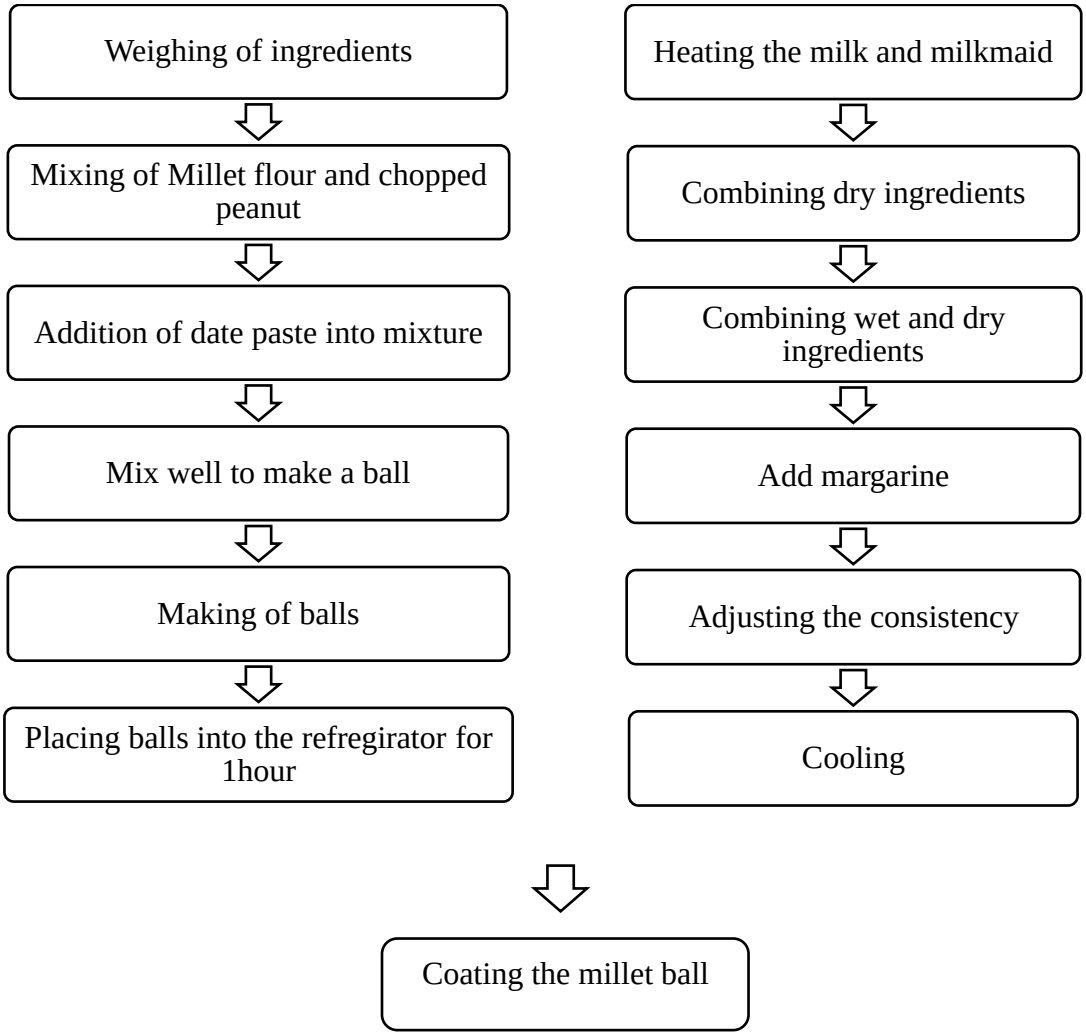

Figure 1: Processing of Chocolate coated millet ball

Sensory Evaluation & Selection

A sensory evaluation was conducted to determine the most preferred formulation among four formulations of chocolate-coated millet balls. Using a five-point hedonic scale, 35 semi-trained panelists assessed key sensory attributes, including overall acceptability. Each panelist received coded samples and completed standardized ballot sheets to rank their preferences. The collected data were analyzed using Friedman's non-parametric statistical test and ANOVA via MINITAB 19 software at a 5% significance level, ensuring results were interpreted with 95% confidence level.

Proximate & Nutritional Analysis

All formulations were tested for moisture and ash content. The selected formulation underwent further analysis for calcium (Ca^{2+}), magnesium (Mg^{2+}), total sugar, crude fat, and crude fibre using standard laboratory methods.

Results and Discussion

Innovative food product development often blends traditional ingredients with modern nutritional goals. This study evaluated four formulations of chocolate-coated millet balls using sorghum, finger, and kodo millets, combined with date paste and chopped peanuts. The aim was to identify the most nutritionally balanced and sensory-preferred combination.

Sensory analysis

The sensory evaluation of four chocolate-coated millet ball formulations demonstrated the influence of millet incorporation on consumer acceptance. While the control sample contained only date paste and peanuts, the millet-based variants offered enhanced sensory and nutritional qualities. Among these, the formulation combining millet, dates, peanuts, and chocolate ganache achieved the highest scores for taste, texture, and overall acceptability, reflecting its balanced flavour profile and appealing mouthfeel. These findings highlight millet's potential as a functional ingredient in snack development, supporting both health-oriented innovation and market appeal through culturally relevant product design.

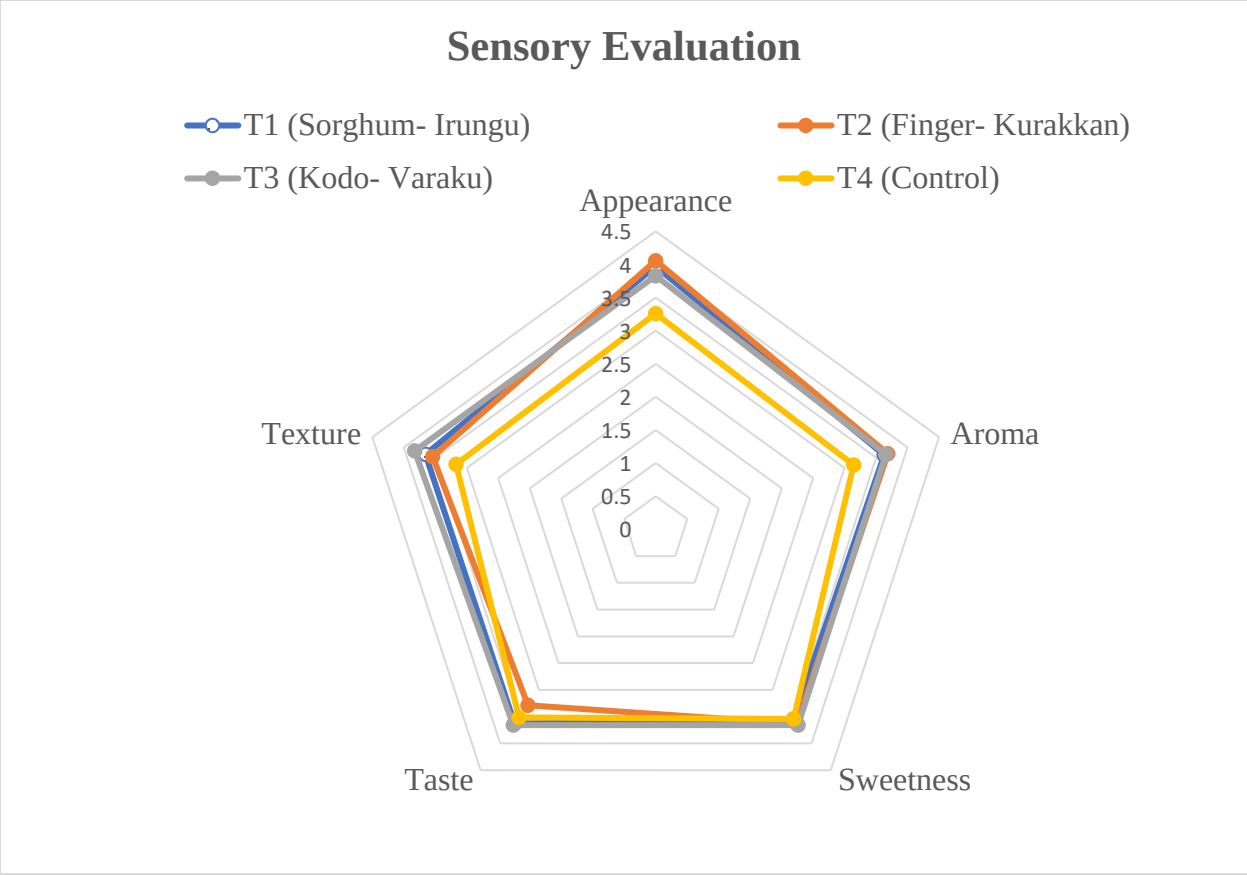

Figure 2: Radar diagram for sensory evaluation of Chocolate coated millet balls

Figure 2 shows a radar map for chocolate-coated millet balls assessing aspects such as appearance, aroma, sweetness, taste, and texture for four samples: T1, T2, T3, and T4. Based on the findings, sample T4 had the lowest score across all attributes, indicating significant areas for improvement. Sample T2 performed better, notably in aroma, sweetness, and taste, indicating a positive sensory profile. Sample T1 performed well in appearance and texture, making it both visually appealing and texturally pleasant. However, aroma and flavor improvements may be beneficial. Sample T3 performed the best overall, with a balanced and extremely acceptable sensory profile. These findings suggest that sample T3 can be used as a baseline for future optimization, while targeted changes to samples T2, T1, and, especially, T4 can improve their general acceptance. This analysis offers significant data for product development and formulation adjustments that are more consumer-focused.

Statistical analysis using ANOVA and the Friedman test confirmed significant differences in appearance and aroma among the formulations. Finger millet achieved the highest scores for appearance, as its fine texture and lighter colour produced a visually appealing product. Sorghum millet contributed to consistency in appearance due to its uniform grain size and smooth surface, which enhanced overall presentation. Kodo millet, with its coarser texture, provided a distinctive crunchiness that improved mouthfeel and added to consumer acceptability. These differences highlight how each millet variety contributes unique sensory qualities, with finger millet excelling in visual appeal, sorghum in uniformity, and kodo millet in texture and eating quality.

Proximate Analysis

Moisture content

Table 3: Moisture content of three different formulations

Formulations	Moisture content
T1	12.827±0.396
T2	15.793±0.456
T3	14.159±0.632

Sorghum millet balls recorded the lowest moisture content (12.83%), which suggests better shelf stability and reduced risk of microbial growth, making them suitable for longer storage. Finger millet balls had the highest moisture content (15.79%), reflecting their fine particle size and protein composition that retain more water. While this contributed to a softer texture, it may reduce shelf life. Kodo millet balls showed moderate moisture retention (14.16%), offering a balance between firmness and palatability.

Ash content

Table 4: Ash content of three different formulations

Formulations	Ash content (%)
T1	1.725±0.177
T2	1.795±0.007
T3	1.500±0.170

Ash content was consistently high across all samples, confirming the mineral richness of millets. Kodo millet had the highest ash value (1.5%), indicating superior mineral composition, particularly calcium, magnesium, and iron. Sorghum and finger millet also contributed significantly, with finger millet showing the most consistency due to its very low standard deviation. These findings demonstrate how millet type influences both product stability and nutritional contribution.

Nutritional Analysis of Selected Formulation (T3)

Table 5: Nutritional percentages of selected formulation (T3)

Nutrient content	Amount
Sugar	15.43%
Fat	10.8%
Fiber	4.42 %
Sodium	39.92mg/100g
Potassium	333.58mg/100g
Calcium	12.02mg/100g
Magnesium	120.21mg/100g

The selected formulation (kodo millet) displayed a well-balanced nutritional profile. Sugar content was moderate (15.43%), derived mainly from dates, making the product healthier than refined sugar-based snacks while still appealing in taste. Fat content (10.8%) was primarily from peanuts and chocolate ganache, providing beneficial unsaturated fats that support satiety and cardiovascular health. Fibre content (4.42%) was notable, aiding digestion, blood sugar regulation, and weight management. Mineral analysis revealed low sodium (39.92 mg/100g), making the product suitable for individuals monitoring salt intake, while potassium levels were high (333.58 mg/100g), helping regulate blood pressure and fluid balance. Calcium (12.02 mg/100g) supported bone strength and muscle function, while magnesium (120.21 mg/100g) contributed to energy metabolism and nerve signaling. Together, these nutrients position the chocolate-coated millet ball as a functional snack that combines indulgence with genuine health benefits.

Selection of Most Preferred Formulation

Based on combined sensory and nutritional data, Formulation 3 (Kodo millet) was identified as the most balanced and acceptable option. It offered a harmonious blend of flavour, texture, and nutritional value, making it suitable for health-conscious consumers. The control formulation lacked the complexity and nutritional depth of millet-based variants.

Conclusion

The study successfully identified the optimal formulation for chocolate-coated millet balls by evaluating sensory attributes and nutritional composition. The combination of 40% millet, 40% date paste, and 20% chopped peanuts consistently outperformed other variants. Among the millet types, chocolate-coated kodo millet (T3) emerged as the most preferred, offering a well-balanced sensory profile and superior nutritional traits, including high fibre, essential minerals, and healthy fats. Comparative analysis confirmed that the control formulation (40% date paste + 60% peanuts) lacked the nutritional and sensory depth of millet-based variants. Sorghum millet balls were visually and texturally strong, while finger millet balls showed promise in aroma and sweetness. However, Kodo millet balls demonstrated the best overall performance. These findings suggest that millet-based snacks, particularly those using Kodo millet, can meet modern consumer demands for taste, nutrition, and cultural relevance. The selected formulation provides a foundation for future product development and commercialization.

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