

Development and Nutritional Analysis of Palmyra Sprout Enriched Cookies Using *Borassus flabellifer*

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ABSTRACT

Palmyra palm (*Borassus flabellifer* L.) sprouts are underutilized indigenous resources with significant nutritional potential for functional bakery product development, particularly for improving protein and fibre content. This study aims to develop palmyra sprout incorporated cookies and evaluate the effects of formulation variations on sensory quality and macronutrient composition. Eight cookie formulations were prepared by partially replacing wheat flour with 10–30% palmyra sprout flour and adjusting sugar and leavening levels. Sensory evaluation was carried out using a nine-point hedonic scale, while protein content was determined by the Lowry method at 490 nm using bovine serum albumin as the standard and carbohydrate content was estimated by the phenol–sulfuric acid method. Formulations containing higher levels of palmyra sprout flour with optimized sugar and leavening showed superior sensory acceptability, with overall scores ranging from 8.6 to 9.2 compared to 6.7 to 7.6 for initial formulations. The optimized palmyra sprout cookies contained 5.2 g protein per 10 g sample, which was higher than conventional wheat-based cookies, while carbohydrate content was 1.98 g per 10 g sample, indicating a favourable shift from a carbohydrate dense product to a protein enriched functional snack. Overall, palmyra sprout flour effectively enhanced nutritional quality and sensory acceptability, demonstrating its suitability as a functional ingredient for health-oriented bakery products and supporting sustainable utilization of indigenous plant food resources.

Keywords: Palmyra sprout cookies; Functional bakery products; Protein enrichment; Plant based nutrition

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Introduction

Cookies are widely consumed bakery products owing to their convenience, extended shelf life, and high consumer acceptability across different age groups. Conventional cookie formulations are primarily based on refined wheat flour, sugar, and fat, which provide desirable sensory properties but are often nutritionally limited, particularly in terms of protein, dietary fibre, and bioactive components (Sudha et al. 2007; Giarnetti et al. 2015). Increasing consumer awareness of diet-related health issues has driven research towards the development of nutritionally enriched bakery products using functional and alternative ingredients.

Palmyra palm (*Borassus flabellifer* L.) is an underutilized tropical species widely distributed in South and Southeast Asia. The sprouts obtained during

seed germination are reported to be rich in carbohydrates, dietary fibre, minerals, and moderate protein content (Balasubramanian and Sreenivasan 2018). Despite their nutritional potential, palmyra sprouts remain largely unexplored for application in processed food products, particularly in bakery formulations. The presence of fibre and bioactive constituents suggests that palmyra sprout flour could serve as a functional ingredient capable of improving the nutritional profile of baked products.

Incorporation of non-wheat flours into cookie formulations has been shown to enhance nutritional quality; however, higher levels of substitution may adversely affect dough handling, texture, colour, and flavour of the final product (Ajila et al. 2008; Filipčev et al. 2011). Therefore, optimization of incorporation

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levels is critical to ensure an appropriate balance between nutritional enhancement and sensory acceptability. Several studies have reported successful enrichment of cookies using legumes, millets, and fruit or vegetable by-products (Sudha et al. 2007; Giarnetti et al. 2015), but limited scientific literature is available on the utilization of palmyra sprout flour in cookie production.

The present study was undertaken to develop cookies enriched with palmyra sprout flour and to evaluate their sensory and nutritional characteristics. The objectives of the study were to optimize the level of palmyra sprout flour incorporation, assess sensory acceptability using a nine-point hedonic scale, and determine the nutritional composition of the developed cookies, with particular emphasis on protein and carbohydrate content. This study aims to contribute to the sustainable utilization of palmyra sprouts as a functional ingredient and support the development of nutritionally improved bakery products.

MATERIALS AND METHOD

Raw materials

Fresh palmyra palm (*Borassus flabellifer* L.) sprouts, refined wheat flour, whole wheat flour, powdered sugar, baking powder, baking soda, and unsalted butter were used for cookie preparation. Palmyra sprouts were selected due to their reported dietary fibre content and techno-functional properties suitable for bakery applications (Khatri et al. 2020; Vengaiah et al. 2019; Bhardwaj and Sivakami 2025; Discover Food 2025). All ingredients were of food-grade quality and were stored in airtight containers at ambient temperature until use.

Preparation of palmyra sprout flour

Fresh palmyra sprouts were washed thoroughly under running water, trimmed, and sliced uniformly. The slices were immersed and boiled in a concentrated sugar solution (approximately 40–50% w/v) for 15 min as an osmotic dehydration pretreatment. The treated slices were drained and dried in a hot-air oven at 60 °C until constant weight was attained. The dried material was milled using a laboratory grinder, passed through a fine sieve, and stored in airtight containers at ambient temperature until further use. Similar processing techniques for palmyra haustorium and fruit-based flours intended for bakery applications have been reported earlier (Vengaiah et al. 2019; Khatri et al. 2020; Vengaiah et al. 2020; Discover Food 2025).

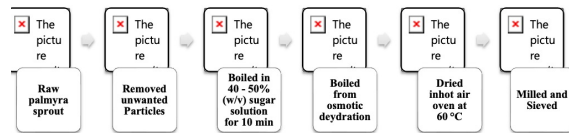


Fig 1: Processing Steps for Osmotically Dehydrated Palmyra Sprout Flour

Cookie formulation

Cookies were formulated by partially substituting wheat flour with palmyra sprout flour at levels ranging from 10 to 30% (w/w, flour basis). Eight preliminary formulation trials were conducted by varying the proportions of palmyra sprout flour, wheat flour, powdered sugar, and leavening agents, while maintaining butter at a constant level of 50 g per 100 g flour. The formulation details of the preliminary trials are presented in Table 1. Previous studies have demonstrated that composite formulations containing 20–30% palmyra sprout or shoot flour result in acceptable baked products with improved fibre content and functional properties (Khatri et al. 2020; Vengaiah et al. 2019; Bhardwaj and Sivakami 2025; Discover Food 2025).

Control cookies were prepared using whole wheat flour and refined wheat flour without the addition of palmyra sprout flour. The formulations used for control samples are shown in Table 2.

Cookie processing

Dry ingredients, including wheat flour, palmyra sprout flour, powdered sugar, baking powder, and baking soda, were mixed thoroughly to ensure uniform distribution. Butter was creamed with powdered sugar until a light and fluffy consistency was obtained, after which the dry ingredient mixture was gradually incorporated to form a homogeneous dough. The dough was sheeted and cut into discs of uniform thickness and diameter. Baking was carried out in a preheated oven at 165 °C for 15 min. The baked cookies were cooled to room temperature and stored in airtight containers for further analyses.

Cookie formulation trials

Trial	Palmyra sprout flour (g)	Whole Wheat flour (g)	Powdered sugar (g)	Baking powder (g)	Baking soda (g)	Butter (g)	Total (g)
1	10	90	50	0.5	0.5	50	211
2	10	90	50	1.0	1.0	50	212
3	20	80	100	1.5	1.5	50	253
4	30	80	65	1.5	1.5	50	248
5	25	75	70	1.5	1.5	50	227

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10	90	50	2.5	.5	0	5
20	80	50	2.5	.5	0	5
30	70	50	2.5	.5	0	5

Table 1: Formulation trials with increasing sprout substitution

Sample	Whole Wheat Cookie (g)	Refined Wheat Cookie (g)	Powdered sugar (g)	Baking powder (g)	Baking soda (g)	Butter (g)	Total (g)
Sample A	100	-	50	1.5	1.0	70	222.5
Sample B	-	120	50	1.5	1.0	50	222.5

Table 2: Whole and Refined Wheat Cookie Formulation (Control)

Sensory evaluation

Sensory evaluation of the cookie samples was carried out by a semi-trained panel using a nine-point hedonic scale, where 1 represented “dislike extremely” and 9 represented “like extremely.” The attributes evaluated included appearance, taste, texture, aroma, flavour, colour, and overall acceptability. Samples were coded and presented to the panelists in randomized order to minimize bias. Similar hedonic sensory evaluation protocols have been widely employed in studies on palmyra-based and composite flour bakery products (Khatri et al. 2020; Peprah et al. 2018; Bhardwaj and Sivakami 2025; Discover Food 2025).

Determination of moisture content

Moisture content of cookie samples was determined by oven-drying at 105 °C to constant weight following standard AOAC procedures (AOAC 2016). A known weight of finely ground cookie sample (W_1) was dried and reweighed (W_2). Moisture content was calculated using the following equation:

$$\text{Moisture (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Determination of Protein Content

Protein content was estimated using the Lowry method. Ground cookie samples were extracted appropriately, and aliquots were reacted with alkaline copper (Biuret) reagent followed by Folin–Ciocalteu reagent. After incubation for colour development, absorbance was measured at 490 nm using a UV–visible spectrophotometer. Protein concentration was

calculated using a bovine serum albumin standard curve and expressed as g/10 g sample. Lowry-type colorimetric assays are widely applied in cereal- and bakery-based product research due to their sensitivity in complex food matrices (Food Chemistry 2019; Sustainable Food Technology 2025). The protein estimation data are presented in Table 3.

Test Tube	S0	S1	S2	S3	S4	S5	T1 Sample A (Wheat Cookie)	T2 Sample B (Refined Wheat Cookie)	T3 Sample C (Palmyra sprout cookie)
Volume of BSA (mL)	0.0	0.2	0.4	0.6	0.8	1.0	–	–	–
Concentration of BSA (µg)	0	20	40	60	80	100	–	–	–
Distilled Water (mL)	1.0	0.8	0.6	0.4	0.2	0.0	1.0	1.0	1.0
Alkaline Copper Reagent (mL)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Folin–Ciocalteu Reagent (mL)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

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Incubate Time (min)	10	10	10	10	10	10	10	10	10
Samples (A, B, C)	–	–	–	–	–	–	0.5	0.5	0.5
Absorbance at 450	0.03	0.16	0.30	0.45	0.61	0.75	0.34	0.29	0.40

Table 3: Protein estimation of cookie samples by the Lowry method

Determination of Carbohydrate content

Total carbohydrate content was determined using the phenol–sulfuric acid method. One millilitre of sample solution was mixed with 1 mL of 5% phenol solution, followed by the addition of 2.5 mL of concentrated sulfuric acid. The reaction mixture was allowed to stand for colour development, and absorbance was measured at 490 nm against a reagent blank. Quantification was performed using a glucose standard curve, and results were expressed as g/10 g sample. This method is commonly used for the estimation of total soluble carbohydrates in cereal- and fibre-based baked products (AOAC 2016; Sustainable Food Technology 2025). The carbohydrate estimation results are shown in Table 4.

Table 4: Carbohydrate estimation of cookie samples by the phenol–sulfuric acid method

Test Tube	S0	S1	S2	S3	S4	S5	T1 Sample A (Whole Wheat Cookie)	T2 Sample B (Refined Wheat Cookie)	T3 Sample C (Palmyra sprout + Wheat Cookie)
Volume of Glucose Standard (mL)	0.0	0.2	0.4	0.6	0.8	1.0	–	–	–
Concentration of Glucose (µg)	0	20	40	60	80	100	–	–	–
Distilled Water (mL)	1.0	0.8	0.6	0.4	0.2	0.0	1.0	1.0	1.0
3% Phenol Solution (mL)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Concentrated Sulfuric Acid (mL)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Incubation Time (min)	20	20	20	20	20	20	20	20	20
Samples (A, B, C)	–	–	–	–	–	–	0.5	0.5	0.5
Absorbance at 490 nm	0.015	0.102	0.198	0.296	0.405	0.498	0.315	0.340	0.255

RESULT AND DISCUSSION

Effect of Formulation Variations on Cookie Properties

Eight formulations (T1–T8) were developed by varying Palmyra sprout flour, wheat flour, sugar and

leavening agents (Table 1). Palmyra sprout flour was incorporated at 10–30 g/100 g of flour blend, partially replacing wheat flour. Powdered sugar ranged from 50 to 100 g, and baking powder/soda from 0.5 to 2.5 g. Butter was kept constant (50 g) to maintain fat level and spread characteristics.

Increasing Palmyra sprout flour (T3, T4, T7, T8) introduced more fibre and protein, expected to affect dough handling, spread, and texture, while adjustments in sugar and leavening were aimed at compensating for these structural changes to achieve desirable volume and sensory quality.

Sensory Acceptability of Cookie Formulations

Sensory evaluation of Palmyra sprout cookies on a 9-point hedonic scale showed that early formulations (T1–T4) with lower leavening and unoptimized sugar achieved only moderate overall acceptability (6.7–7.6). Optimized formulations (T5–T8), containing higher Palmyra sprout flour (25–30%), balanced sugar (65–70 g) and increased baking powder/soda (2.5 g), obtained significantly higher scores for all attributes, with overall acceptability ranging from 8.6 to 9.2.



Fig 2: Developed palmyra sprout cookies

Developed palmyra sprout cookies

Trial T8 (30% Palmyra sprout flour) was most preferred, indicating good consumer acceptance of the characteristic flavour and darker colour of Palmyra sprout, along with a light, crisp texture. Overall, up to 30% replacement of wheat flour with Palmyra sprout flour, with appropriate adjustment of sugar and leavening, produced cookies with superior sensory quality and high consumer acceptability, while potentially enhancing nutritional value.

Table 5: Sensory evaluation of cookie samples using a 9-point hedonic scale

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Trial	Appearance	Taste	Texture	Aroma	Flavor	Color	Overall acceptability
1	7.1	7.1	7.3	7.0	--	--	7.3
2	6.8	7.1	7.0	6.5	--	--	6.7
3	7.6	7.5	7.1	7.3	--	--	7.6
4	7.1	6.8	6.8	7.6	--	--	7.3
5	8.2	8.3	8.0	8.1	8.2	8.3	8.6
6	8.3	8.4	8.1	8.2	8.3	8.4	8.7
7	8.4	8.5	8.2	8.3	8.4	8.5	8.8
8	8.6	8.7	8.4	8.5	8.6	8.7	9.2

Trial	Appearance	Taste	Texture	Aroma	Flavor	Color	Overall Acceptability
Sample A (Whole Wheat Cookie)	8.9	8.8	8.7	8.8	8.7	8.9	9.0
Sample B (Refined Wheat Cookie)	8.9	8.7	8.8	8.8	8.7	9.1	8.9

Table 6: Sensory Evaluation of Sample A and B

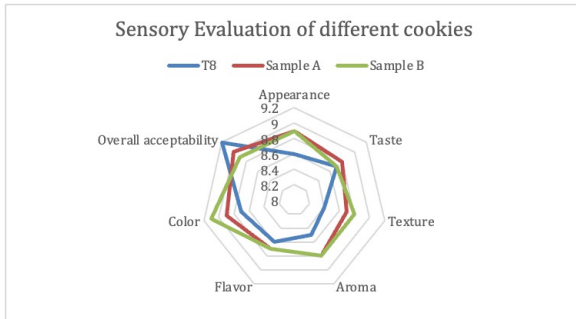


Fig 3: Radar graph for cookie

Moisture Content

Parameter	Whole Wheat Cookie	Refined Wheat Cookie	Palmyra sprout Cookie (T8)
Moisture (%)	5.10	4.30	7.64

Table 7: Moisture percentage of different cookie formulations

The higher moisture content in the Palmyra sprout-incorporated cookie (T8) can be attributed to the increased water-binding capacity of dietary fibre present in Palmyra sprout flour. Similar moisture retention in fibre-enriched cookies has been reported due to the presence of hydrophilic functional groups (Sudha, Vetrmani, & Leelavathi, 2007; Ajila, Leelavathi, & Prasada Rao, 2008). This increased moisture contributed to a softer texture and delayed staling, while remaining within acceptable limits for cookie shelf stability (Mildner-Szkudlarz et al., 2015).

Protein Content

Using the Lowry method ($\lambda = 490$ nm, BSA standard), Palmyra sprout cookies contained 5.2 g protein per 10 g sample. This confirms Palmyra sprout flour as a major protein contributor in the formulation, shifting the product from a conventional carbohydrate-rich cookie toward a protein-dense functional snack. Such enrichment is nutritionally relevant in contexts where plant-based proteins are promoted to improve dietary quality.

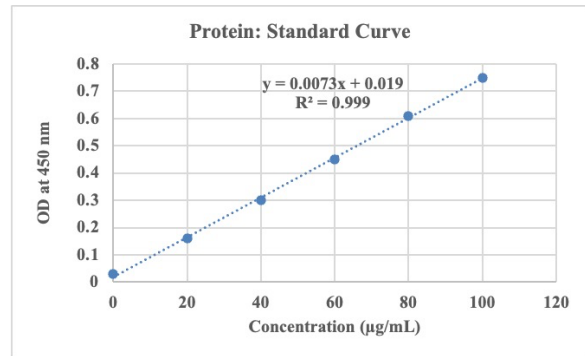


Fig 4: Protein standard curve (BSA) at 450 nm

Protein Concentration Calculation (µg/mL)

Standard Curve Equation

$$y = 0.00729x + 0.019$$

Formula used:

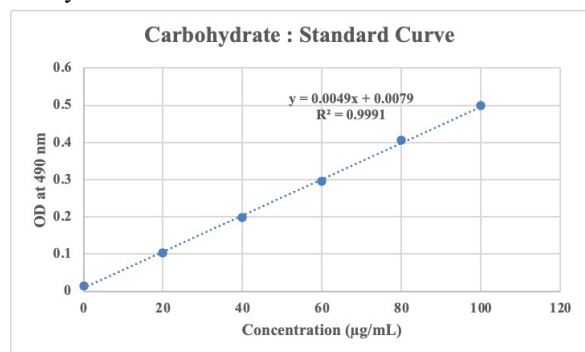
$$x = \frac{(0.019)}{0.00729}$$

Parameter	Whole Wheat Cookie	Refined Wheat Cookie	Palmyra sprout + Wheat Cookie (T8)
Protein (g/10 g)	4.4	3.8	5.2g

Table 8: Comparative protein content of different cookie formulations

Carbohydrate Content

Carbohydrate content was 1.98 g per 10 g cookie sample, derived mainly from wheat flour, Palmyra sprout flour and added sugar. Although numerically low for a baked cereal product and suggesting the need for re-checking analytical and calculation procedures, the formulation conceptually aims at lower available carbohydrates and higher protein-fibre fractions. This macronutrient shift supports positioning Palmyra sprout cookies as a health-oriented, energy-providing bakery product with potential benefits for consumers seeking moderated carbohydrate intake and enhanced satiety.



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Fig 5: Carbohydrate standard curve (glucose) at 490 nm

Carbohydrate Concentration Calculation ($\mu\text{g/mL}$)

Standard Curve Equation

$$y = 0.0049x + 0.0079$$

Formula used:

$$x = \frac{(0.0079)}{0.0049}$$

(after dilution factor and expressing per 10 g sample)

Parameter	Whole Wheat Cookie	Refined Wheat Cookie	Palmyra sprout + Wheat Cookie (T8)
Carbohydrate (g/10 g)	2.45	2.70	1.98

Table 9: Comparative nutritional profile of Palmyra sprout cookies and control cookie

CONCLUSION

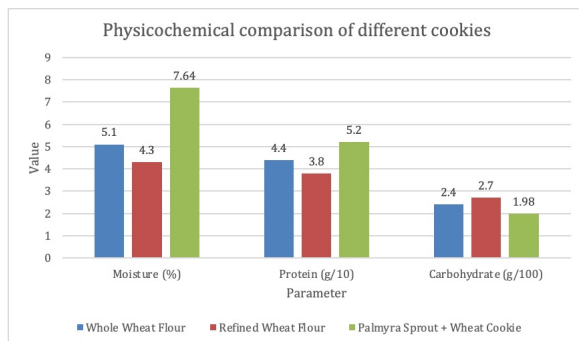


Fig 6: Physicochemical comparison of different cookie

The physicochemical evaluation of cookies formulated with whole wheat flour, refined wheat flour, and palmyra sprout-wheat flour demonstrated significant compositional variations among the formulations. Cookies enriched with palmyra sprouts exhibited a higher moisture content (7.64%), indicating enhanced water-binding capacity, which may positively influence product freshness and textural stability. The palmyra sprout cookies showed an increased protein content (5.2 g/10 g) compared with whole wheat (4.4 g/10 g) and refined wheat cookies (3.8 g/10 g), highlighting the nutritional contribution of palmyra sprouts. In contrast, carbohydrate content was comparatively lower (1.98 g/100 g) in the palmyra sprout-wheat formulation.

Overall, the incorporation of palmyra sprouts into wheat-based cookie formulations significantly improved the nutritional profile by enhancing protein content while moderating carbohydrate levels. These findings support the potential application of palmyra sprouts as a functional ingredient in bakery products aimed at developing value-added foods with improved nutritional quality.

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