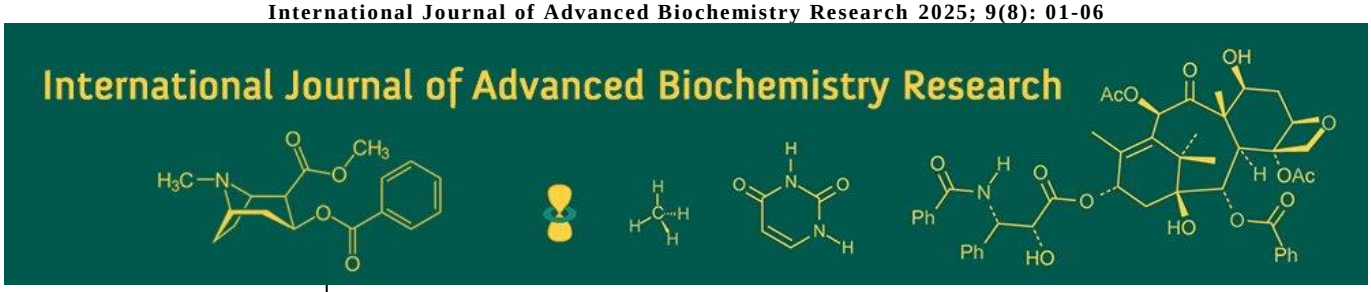

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(8): 01-06
www.biochemjournal.com
Received: 01-05-2025
Accepted: 03-06-2025

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Exploring the culinary versatility of tendu (*Diospyros melanoxylon* roxb.) fruit by formulating value added products and their quality evaluation

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i8a.5067

Abstract
This study investigates the culinary possibilities of tendu (*Diospyros melanoxylon* Roxb.) fruit by creating and assessing six value-added food products. Although indigenous communities have traditionally used tendu fruit, it remains significantly underexploited in the commercial food industry. The fruit is abundant in carbohydrates, vitamin C, potassium, and tannins, providing an opportunity to diversify functional food options. From the raw tendu fruit pulp, three products were developed: pickle, chutney, and candy; and from the ripe pulp, three products were created: mouth freshener, energy bar, and smoothie, all in dried and powdered forms. Various physical aspects (fruit diameter, fresh weight, peel weight, pulp weight, and seed weight), physicochemical characteristics (pH, titratable acidity, pectin content, and total sugar), and proximate composition (moisture, protein, fiber, fat, ash, carbohydrate, energy, vitamin C, potassium, and tannin presence) were analyzed. A sensory evaluation was performed using a 9-point hedonic scale, and shelf-life studies (moisture content, sensory ratings, and peroxide values) were conducted over a 60-day period for all products except the smoothie. The findings revealed that ripe tendu pulp had a greater pulp yield and sugar content, making it more suitable for sweet applications, while the raw pulp was better suited for savory and preserved dishes. Among the products created, chutney and energy bars received the highest sensory ratings at 0 and 30 days of storage. Nonetheless, all products exhibited signs of deterioration after 45 days, as indicated by declining sensory acceptability and rising peroxide values, highlighting the limits of shelf stability. This study illustrates the practicality of integrating tendu fruit into diverse food formulations, thereby creating opportunities for improved nutrition and income generation through forest-based value addition.

Keywords: *Diospyros melanoxylon*, tendu fruit, value addition, sensory evaluation, shelf life, proximate composition

Introduction
Diospyros melanoxylon Roxb., often referred to as tendu or kendu, is a deciduous tree in the Ebenaceae family, primarily located in central and southern India. Although the leaves of this tree are heavily utilized in the bidi industry, its fruits have historically been underutilized, even though they are traditionally consumed by indigenous populations. Tendu fruits are seasonal and highly nutritious, particularly rich in carbohydrates, vitamin C, potassium, and tannins, which offer considerable potential for both nutritional benefits and commercial use. The fruit can be found in both raw and ripe states, each showcasing distinct organoleptic and physicochemical traits, thereby allowing for various culinary applications.
Recent years have seen an increased focus on underexploited fruits in response to the urgent need for food variety, nutrition security, and income opportunities through enhanced value. Numerous forest-sourced fruits, like tendu, which have been largely neglected, hold promise for creating nutritionally dense, shelf-stable products. These initiatives are in line with the global movement towards sustainable food systems that incorporate biodiversity into everyday diets, minimize food waste, and value indigenous knowledge.
While tendu fruits show potential in terms of nutrition, they are highly perishable and tied to their seasonal availability. Therefore, it is crucial to develop preservation methods and convert them into value-added products to prolong their usability.

Existing research on tendu primarily highlights its medicinal properties, with limited attention given to its culinary or food-related uses. There is a lack of comprehensive studies that systematically assess the sensory profiles, nutritional content, and shelf stability of products made from tendu fruit pulp. This research aims to fill that gap by creating and evaluating innovative food products using both raw and ripe tendu fruit pulp in powdered format.

The focus of this research is on the creation of six value-added products utilizing tendu fruit: pickle, candy, and chutney from the raw fruit, and mouth freshener, energy bar, and smoothie from the ripe fruit. The quality metrics assessed include the physical properties of the fruit, its proximate and physicochemical composition, sensory characteristics, tannin content, and the shelf life of the products over a period of 60 days. All formulations were generated using straightforward, non-mechanized techniques that can easily be replicated at the rural or cottage industry level.

The innovation of this study lies in its comprehensive approach to product development, encompassing everything from the characterization of raw materials to sensory evaluation and shelf-life testing. By utilizing tendu fruit in powdered form, the study also emphasizes an effective method of preservation. The findings of this research are anticipated to enhance the utilization of tendu fruit, improve nutritional choices, and support sustainable livelihoods in communities depending on forest resources.

This paper outlines the detailed results of the study, organized into sections addressing physical and chemical characterization, proximate analysis, product formulation, sensory evaluation, and the evolution of quality metrics during storage. The data was statistically analyzed to assess the acceptability and stability of the products developed.

Methodology: The research aimed to assess the culinary uses of tendu fruit by creating six value-added products. The methodological approach was structured to evaluate the physical, chemical, nutritional, and sensory characteristics of the products derived from both raw and ripe tendu fruit.

1. Raw Material Procurement and Preparation: Tendu fruits were procured from the tribal regions of southern Rajasthan during March to May. After cleaning and sorting, the fruits were categorized into raw and ripe stages based on skin color and firmness. The fruits were sliced, deseeded, and dried under hygienic conditions. The dried slices were powdered and stored in airtight containers for subsequent use in product formulation.

2. Product Formulation: Six different products were developed: pickle, chutney, and candy from raw tendu powder, and mouth freshener, energy bar, and smoothie from ripe tendu powder. Recipes were standardized using preliminary trials. All products were prepared using traditional, equipment-free methods, suitable for small-scale or cottage industry replication.

3. Physical Characterization: Physical attributes of tendu fruit (diameter, fresh weight, peel weight, pulp weight, and seed weight) were recorded using standard manual techniques. Each measurement was replicated and the mean values calculated.

4. Physicochemical Analysis: Physicochemical properties including pH (digital pH meter), titratable acidity (AOAC method), pectin content (sodium hexametaphosphate extraction), and total sugar content (Lane and Eynon method) were analyzed using standard protocols from FSSAI and AOAC.

5. Proximate Composition: Moisture, crude protein, crude fibre, total fat, ash, carbohydrates (by difference), energy value (calculated using Atwater factors), vitamin C (titrimetric method), and potassium content (flame photometry) were determined using AOAC/FSSAI approved methods. Tannin presence was evaluated qualitatively using $FeCl_3$ reagent.

6. Sensory Evaluation: Sensory characteristics such as appearance, texture, taste, aroma, and overall acceptability were evaluated by a semi-trained panel of 10 members using a 9-point hedonic scale. Evaluations were conducted on freshly prepared products and again at storage intervals.

7. Shelf Life Study: All products except smoothie were stored under ambient conditions and evaluated at 0, 30, 45, and 60 days for sensory score, moisture content (gravimetric method), and peroxide value (fat oxidation indicator).

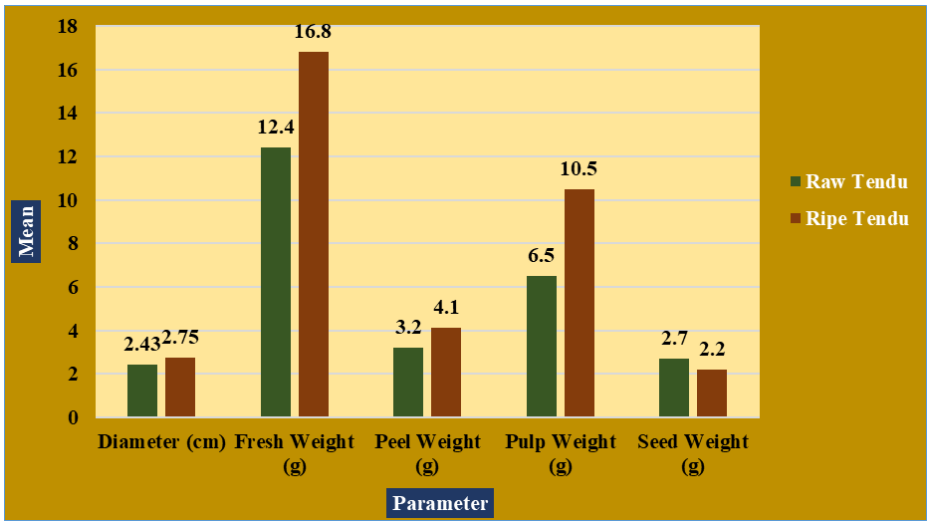
8. Statistical Analysis: All analyses were conducted in triplicates. Mean and standard deviation were calculated for each parameter. Descriptive statistics were used for sensory data. Trends across storage intervals were analyzed graphically

3. Results

3.1 Physical Parameters of Tendu Fruit

Table 3.1: Physical Parameters of Tendu Fruit

Parameter	Raw Tendu (Mean± SD)	Ripe Tendu (Mean± SD)
Diameter (cm)	2.43±0.21	2.75±0.18
Fresh Weight (g)	12.40±1.30	16.80±1.60
Peel Weight (g)	3.20±0.40	4.10±0.30
Pulp Weight (g)	6.50±0.60	10.50±0.80
Seed Weight (g)	2.70±0.30	2.20±0.20

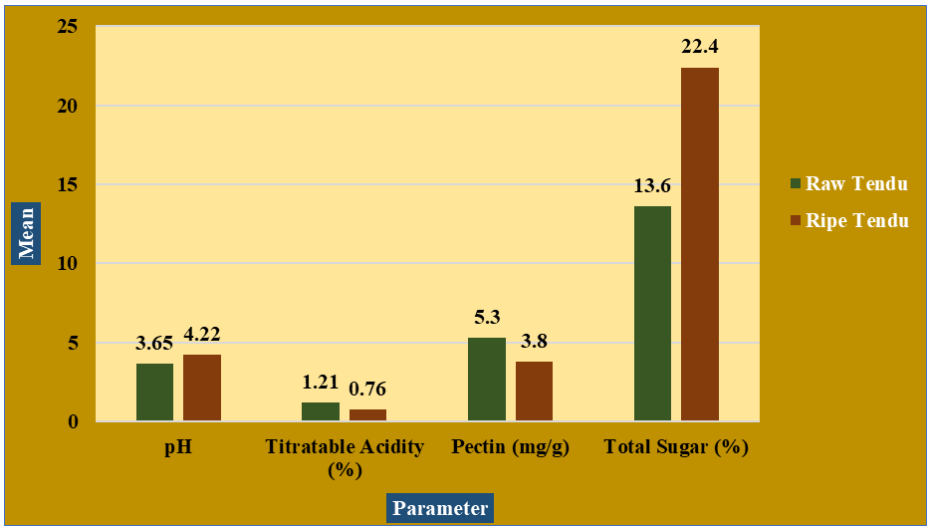


The ripe tendu fruits exhibited a larger diameter (2.75 cm) and higher fresh weight (16.80 g) than raw fruits. As the fruit ripened, pulp weight increased significantly, while seed weight slightly decreased, indicating enhanced edibility and processing potential in ripe tendu.

3.2 Physicochemical Properties of Tendu Fruit

Table 3.2: Physicochemical Properties of Tendu Fruit

Parameter	Raw Tendu (Mean ±SD)	Ripe Tendu (Mean ±SD)
pH	3.65±0.02	4.22±0.03
Titratable Acidity (%)	1.21±0.05	0.76±0.03
Pectin (mg/g)	5.30±0.30	3.80±0.20
Total Sugar (%)	13.60±0.50	22.40±0.60

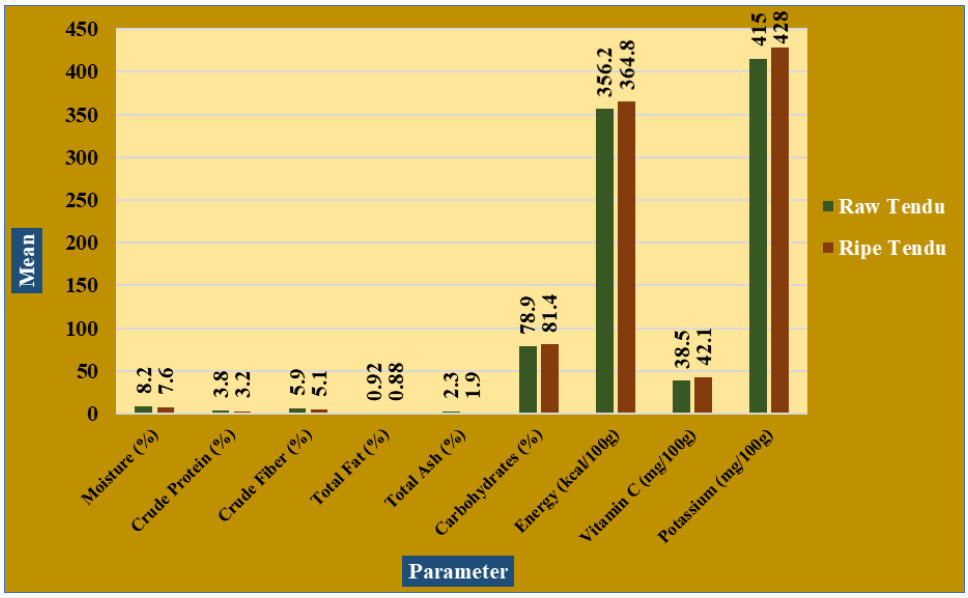


Ripe tendu fruit showed higher pH and sugar content but lower titratable acidity and pectin than the raw fruit. These changes are typical of fruit ripening and support the use of ripe tendu in sweetened and processed products.

3.3 Proximate Composition of Tendu Powder

Table 3.3: Proximate Composition of Tendu Powder

Parameter	Raw Tendu (Mean ±SD)	Ripe Tendu (Mean ±SD)
Moisture (%)	8.20±0.30	7.60±0.20
Crude Protein (%)	3.80±0.10	3.20±0.10
Crude Fiber (%)	5.90±0.20	5.10±0.20
Total Fat (%)	0.92±0.03	0.88±0.02
Total Ash (%)	2.30±0.10	1.90±0.10
Carbohydrates (%)	78.90±0.40	81.40±0.30
Energy (kcal/100g)	356.20±3.50	364.80±3.70
Vitamin C (mg/100g)	38.50±1.60	42.10±1.70
Potassium (mg/100g)	415.00±12.00	428.00±14.00
Tannin	Present	Present

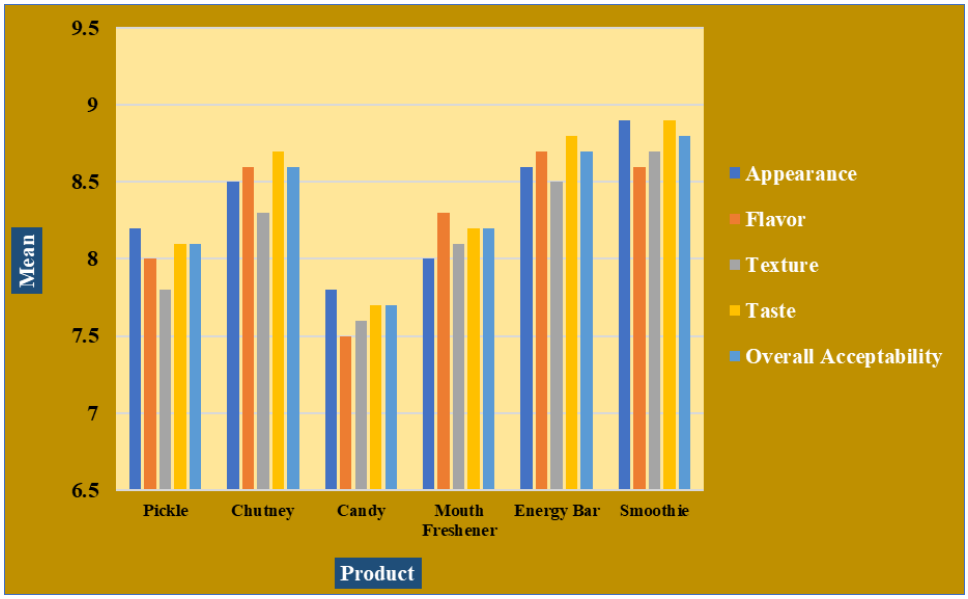


Both raw and ripe tendu powders were found to be rich in carbohydrates and energy, making them suitable for high-energy food formulations. Ripe tendu had slightly higher carbohydrate, vitamin C, and potassium content, while raw tendu had higher protein, fiber, and ash values**.**

3.4 Sensory Evaluation of Value-Added Products (0 Day)

Table 3.4: Sensory Evaluation of Value-Added Products (0 Day)

Product	Appearance (Mean ±SD)	Flavor (Mean ±SD)	Texture (Mean ±SD)	Taste (Mean ±SD)	Overall Acceptability (Mean ±SD)
Pickle	8.20±0.30	8.00±0.40	7.80±0.20	8.10±0.30	8.10±0.20
Chutney	8.50±0.20	8.60±0.20	8.30±0.20	8.70±0.30	8.60±0.30
Candy	7.80±0.30	7.50±0.40	7.60±0.30	7.70±0.30	7.70±0.20
Mouth Freshener	8.00±0.30	8.30±0.20	8.10±0.30	8.20±0.30	8.20±0.20
Energy Bar	8.60±0.20	8.70±0.30	8.50±0.20	8.80±0.30	8.70±0.30
Smoothie	8.90±0.20	8.60±0.20	8.70±0.20	8.90±0.30	8.80±0.20



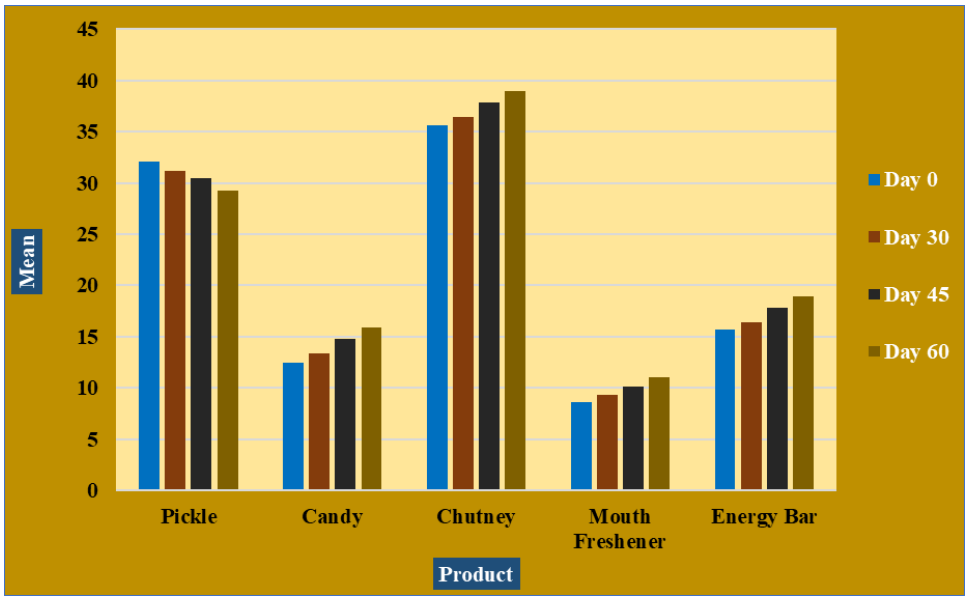
All products scored high in sensory attributes on the first day, with the smoothie and energy bar showing the highest overall acceptability. This confirms the consumer appeal of tendu-based value-added formulations.

3.5 Shelf-Life Study

3.5.1 Moisture Content of Value-Added Products Over Storage (0, 30, 45, 60 Days) (% w.b.)

Table 3.5: Moisture Content of Value-Added Products Over Storage (0, 30, 45, 60 Days) (% w.b.)

Product	Day 0 (Mean ±SD)	Day 30 (Mean ±SD)	Day 45 (Mean ±SD)	Day 60 (Mean ±SD)
Pickle	32.10±0.50	31.20±0.40	30.50±0.60	29.30±0.80
Candy	12.50±0.30	13.40±0.40	14.80±0.50	15.90±0.60
Chutney	35.60±0.60	36.40±0.50	37.80±0.70	39.00±0.80
Mouth Freshener	8.60±0.20	9.30±0.30	10.10±0.30	11.00±0.40
Energy Bar	15.70±0.40	16.40±0.50	17.80±0.60	18.90±0.70

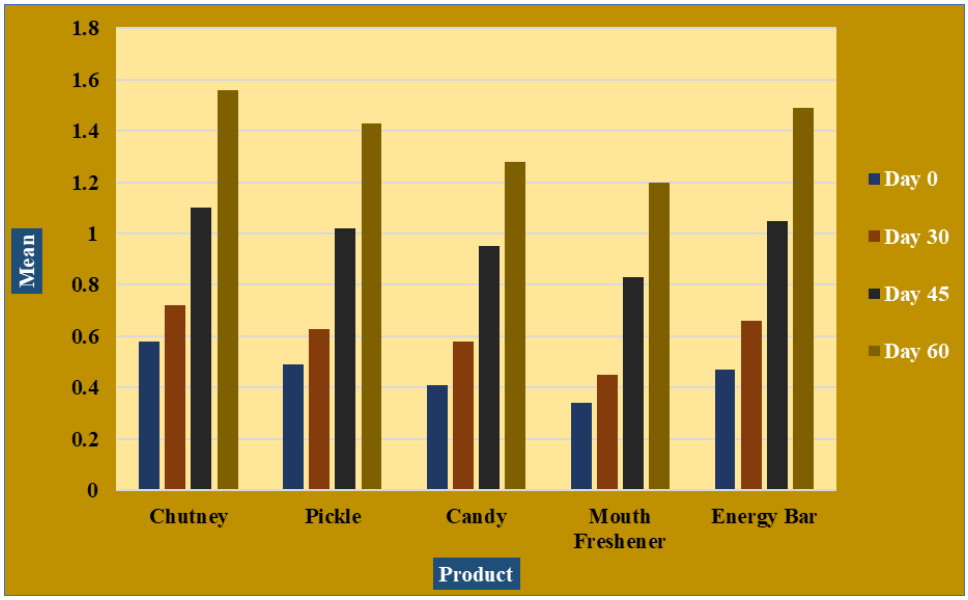


An increase in moisture content was observed in all products over the storage period, particularly after 45 days, which may create favourable conditions for microbial growth and reduce shelf stability.

3.5.2 Peroxide Value of Value-Added Products over Storage (meq O_2/kg fat)

Table 3.6: Peroxide Value of Value-Added Products over Storage (meq O_2/kg fat)

Product	Day 0 (Mean ±SD)	Day 30 (Mean ±SD)	Day 45 (Mean ±SD)	Day 60 (Mean ±SD)
Chutney	0.58±0.04	0.72±0.06	1.10±0.08	1.56±0.10
Pickle	0.49±0.03	0.63±0.04	1.02±0.06	1.43±0.08
Candy	0.41±0.03	0.58±0.03	0.95±0.05	1.28±0.07
Mouth Freshener	0.34±0.02	0.45±0.03	0.83±0.04	1.20±0.06
Energy Bar	0.47±0.03	0.66±0.04	1.05±0.07	1.49±0.08



Peroxide values increased with storage time in all products. Most products exceeded 1.0 meq O_2/kg after 45 days, indicating the onset of lipid oxidation and reducing the sensory and nutritional quality of the products. Hence, tendu-based products were found unsuitable for consumption beyond 45 days of storage under ambient conditions.

3.5.3 Sensory Decline over Storage: Sensory scores declined acrosss all parameters after 45 days, with noticeable off-flavors and textural changes observed, especially in chutney and candy.

All products became unsuitable for consumption after 45 days due to spoilage indicators such as increased peroxide value, moisture retention, and unacceptable sensory attributes.

Discussion

The results of this study highlight the significant culinary and nutritional promise of tendu fruit. The physical attributes of the fruit, such as its pulp-to-seed ratio and pulp yield, suggest that it is a valuable raw material for developing new products. Ripe tendu fruits exhibited a greater pulp weight and sugar content, making them suitable for sweeter preparations such as mouth fresheners and energy bars. The physicochemical tests indicated that raw tendu has high acidity, which makes it ideal for use in pickles and chutneys. Additionally, the substantial pectin content helps improve the structure of preserved products. These characteristics support the culinary categorization and product selection described in this research. The analysis of the proximate composition of tendu revealed that it is rich in moisture, fiber, vitamin C, potassium, and carbohydrates-nutrients essential for a balanced diet. These results are in line with previous studies that have highlighted the functional and nutritional advantages of lesser-known forest fruits. The sensory assessment showed a favorable acceptance of the products developed. Chutney and energy bars received particularly high ratings across various attributes. These items, created using traditional methods and minimal processing, also match local tastes and could be integrated into rural entrepreneurship initiatives. The shelf-life assessment demonstrated that all products remained stable for up to 30 days, with gradual degradation evident after 45 days. By the 60-day mark, both sensory evaluation and peroxide values indicated spoilage, making the products unsuitable for consumption. This finding points to the necessity for enhanced packaging, storage solutions, or natural preservatives to improve product longevity.

Conclusion

This study showcases the untapped potential of tendu (*Diospyros melanoxylon* Roxb.) fruit in creating nutritious and sensory-appealing value-added products. Both raw and ripe forms can be processed into enjoyable products such as pickles, chutneys, candies, mouth fresheners, energy bars, and smoothies. The formulations made from powdered pulp maintained acceptable quality for up to 30 days, with clear spoilage occurring after 45 days.

This research lays the groundwork for the broader use of tendu in the food sector, particularly in regions rich in forests. It also emphasizes the role of underutilized fruits in enhancing dietary diversity and fostering income-generating opportunities through value addition. Future research could investigate prolonged shelf life using improved preservation techniques or the addition of natural antioxidants.

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