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Nutritional and functional characterisation of *Borassus flabellifer* L. tuber with subsequent incorporation into value-added products.

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Abstract

Palmyra tuber (*Borassus flabellifer* L.), a traditional, underutilised crop with numerous nutritional and nutraceutical properties, has the potential to be incorporated into modern-day foods to add value. This study aimed to explore the nutritional potential of processed palmyra tuber flour for use in value-added food products, promoting sustainable utilisation of this indigenous resource. Locally sourced tubers were cleaned, sun-dried for two days, and processed into fine flour. Debittering was done using cold extraction to remove its natural bitterness. The flour underwent nutrient and phytochemical analysis, and FTIR spectrometry was used to identify functional groups. Results indicated high levels of proteins (5.74g/100g), fibre (7.71g/100g) and iron (7.92mg/100g). Phytochemical screening confirmed the presence of flavonoids, alkaloids, anthraquinones, and phenolic compounds, along with functional groups such as alkenes, alkanes, phenols, amines, and hydroxyl groups. Value-added products 'murukku', soup sticks, biscuits, crackers and chocolates were developed and evaluated. Sensory analysis showed favourable acceptance at 30% inclusion for *murukku*, 25% for soup sticks and 60% for the remaining products. Nutritional enrichment in proteins, fibre, iron and calcium was observed. Shelf-life analysis revealed product stability for 28 days, except for soup sticks, which were 14 days. These findings highlight the potential of palmyra tuber flour as a sustainable, nutrient-rich food ingredient.

Keywords*: Borassus flabellifer* L. tuber flour, FTIR spectroscopy, Nutritional profiling, Phytochemical screening, Sensory evaluation, Value-added products

Introduction

Borassus flabellifer L., commonly known as the palmyra palm, is derived from the Greek words 'Borassus' and 'flabellifer', which mean fruit with a leather covering and fanbearer, respectively (Kurian et al., 2017). The palmyra palm is widely cultivated throughout India in different soil types and climate zones. Among all states, Tamil Nadu is the largest producer of palmyra fruit in India. The palmyra palm is the state tree of Tamil Nadu, and it is also considered to be a nature's perennial gift that could flourish well in arid and semi-arid conditions and also could withstand any adverse climatic conditions. The plant has a very close connection with the rural livelihood, cottage and agriculture-based industries of the Indian economy (Krishnaveni et al., 2020).

The palmyra palm provides a wide range of edible and non-edible products which are useful for multiple purposes. The study utilises the palmyra tuber, also known as the palmyra sprouts. Sprouts are produced from mature palm seed. This sprout is a forgotten traditional food and one of the oldest fibre sources found in South Indian cuisines. Their numerous health benefits and advantages make them an amazing health supplement too (Upadhyaya and Sonawane 2022). The expressed juice and decoction are used to counteract poisoning. It was extensively used in folk medicine, especially for liver disorders. The sprout is considered to possess cooling, restorative, diuretic and anthelmintic effects. These tubers are high in crude fibre and carbohydrate and also rich in minerals such as iron, calcium, zinc and a good source of vitamin E. The tuber is also low in fat and glycaemic index. During sprouting, phytonutrient content increases as compared to seeds and consumption of these sprouts is the best way to gain all the health benefits. Regular consumption of palmyra tuber flour increases body strength and reduces hunger. Mixing palmyra tuber flour with other foods is said to positively reduce malnutrition. The palmyra tuber is traditionally consumed either by boiling or by heating in an open fire, but is not widely consumed by people all over India. However, the excellent nutritional and therapeutic value of this underutilised agricultural crop have great potential for processing into various quality products (Korese et al.,2021). Palmyra tuber flour was previously incorporated into noodles, and it was found to be acceptable at 35 per cent along with whole wheat flour at 65 per cent. The study also reported that the noodles showed greater antioxidant and phenolic activity with an increase in calcium and

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magnesium levels (Ambikaipahan et al., 2020). Similarly, the debittered palmyra young shoot flour was used to make a traditional Indian sweet (Gulab jamun) that had higher protein and fibre content compared to the commercial sample (Perumal et al., 2019). Devi and Sharmila (2019) prepared palmyra tuber flour, along with jaggery and millets, and incorporated this powder into Nutri balls. The Nutri ball with 25 per cent of palmyra tuber flour was found to have the best sensory acceptability. Incorporation of palmyra tuber flour significantly improved the sensory profile. The shelf life of the Nutri ball was reported to be 30 days. Therefore, the present study was designed primarily with the objective of exploring the nutritional potential of processed palmyra tuber flour for use in value-added food formulations, which can pave the way as a sustainable approach towards valorising underutilised crops.

Materials and methods

Palmyra tuber, also known as palmyra sprout, was selected for the study and procured from a local vendor in Coimbatore, Tamil Nadu, in the month of January. To increase the nutritional content of the formulated food products, soy flour and foxtail millet flour were included. Soy flour and foxtail millet flour were procured from an organic store in Coimbatore, Tamil Nadu.

Processing of palmyra tuber into flour

The palmyra tuber was observed for its morphological characteristics. The tuber was then cleaned, the outer brown peel was removed, the fibrous scales from the surfaces were scraped off, the tuber was longitudinally halved, and the central transparent vascular cylinder, which is inedible, was removed. The tuber was then washed under running tap water and was chopped into small pieces and sundried for two days in a clean place. Once all the moisture had evaporated, the tuber pieces were pounded manually and then processed into fine flour using a laboratory mixer grinder. The yield per cent of the flour was calculated.

Debittering of palmyra tuber flour

Palmyra tuber flour has a characteristic bitter taste due to the presence of the compound flabelliferin and saponins, which limit its utilisation; therefore, it is essential to subject the flour to debittering. The flour was debittered using the cold extraction method as described by Sharaniya and Navaratnam (2015). In a one litre beaker, 250g of palmyra tuber flour was mixed with 400 ml of distilled water and left undisturbed at room temperature for one hour. After one hour, the water was drained off, and this process was repeated twice. Following the third extraction, the wet flour was filtered through a muslin cloth to remove excess water, and then sun-dried for three hours.The dried flour was stored in zip-lock pouches for further analysis and formulations.

Analysis of the nutrient content of debittered palmyra tuber flour

It is essential to analyse the nutrient content of debittered palmyra tuber flour to understand its potential to be utilised in food formulations. Therefore, the flour was analysed for moisture, energy, carbohydrates, proteins, fats, fibre, iron and calcium using standard analytical methods as mentioned in Table 1

Table 1. Nutrients analysed and analytical methods adopted.

Nutrients	Methods Adopted
Moisture	FSSAI, 2016
Energy	Atwater formula (FAO, 2003)
Carbohydrates	Difference method (AOAC, 1990)
Proteins	Kjeldhal's method
Fats	Soxhlet method, AOAC 948.22 17th Edition
Fibre	AOAC 935.53 17th Edition
Calcium (Ca)	AOAC999.19 19th Edition
Iron (Fe)	AOAC999.19 19th Edition

FSSAI:Food Safety and Standards Authority of India; FAO:Food and Agriculture Organisation; AOAC: Association of Official Analytical Chemists

Nutritional parameters of the samples were estimated using standard procedures. Moisture content was determined as per Food Safety and Standards Authority of India (FSSAI, 2016), while energy was calculated using the Atwater factor method (Food and Agriculture Organisation, 2003). Carbohydrate content was estimated by the difference method (Association of Official Analytical Chemists, AOAC 1990), protein by Kjeldahl's method, fat by Soxhlet extraction (AOAC 948.22, 17th Ed.), fibre by AOAC 935.53 (17th Ed.), and calcium and iron by AOAC 999.19 (19th Ed.).

Phytochemical analysis of debittered palmyra tuber flour

Phytochemicals are biologically active compounds that can have positive or negative health impacts. Phytochemicals are proven to show biological activity when consumed by humans; they have been associated with the prevention and treatment of chronic diseases, hence their identification is important (Junaid and Patil, 2020). Therefore, standard qualitative phytochemical screening was performed in debittered palmyra tuber flour.

Identification of functional groups using FTIR analysis

Functional groups are part of a molecule that undergo certain reactions, which are responsible for defining the chemical properties of a sample. Hence, identification of functional groups is essential. Fourier Transform Infrared Spectrophotometer (FTIR) is a rapid and powerful tool for identifying the types of functional groups. As can be seen in the annotated spectrum, the wavelength of light that is absorbed is indicative of the chemical bond. It is possible to identify the chemical bonds of a molecule by analysing its infrared absorption spectrum (Prasad et al., 2022). For FTIR analysis, dried sample extracts in a methanolic solvent were employed as powder. About 100 mg of the KBr pellet was used to encapsulate 10 mg of the dried extract powder. The powdered sample was fed into a Japanese-made FTIR spectroscope (Shimadzu, Miracle 10) with a scan range of 400 to 4000 cm. By scanning the wavelength of the light passing through thesample, the spectrometer detects the transmitted radiation and logs the absorption spectrum (Enders et al., 2021)

Formulation of value-added food products

The debittered palmyra tuber flour, along with other ingredients, was used to formulate value-added murukku, biscuits, crackers, soup sticks and chocolates. The selection of products was based on their popularity and feasibility to be combined with the palmyra tuber flour. The optimal levels of palmyra tuber flour to be incorporated in each product were determined by various trials and errors.

Murukku is a traditional savoury snack prepared primarily from rice flour in combination with split black gram (urad dal) flour, salt and spices. Murukku were prepared following the method described by Philip, (2010). A standard was prepared with the same method using rice flour and split black gram flour alone.The treatments were prepared with 25, 30 and 35 per cent of debittered palmyra tuber flour as T_1, T_2 and T_3, respectively.

Biscuits are baked snacks that can be sweet, savoury or both. Biscuits are usually prepared with refined flour as the base ingredient and other baking ingredients. Biscuits were prepared using the traditional creaming method described by Adeola et al. (2018) with slight modifications. Biscuits that were made from 100 per cent wheat flour served as the standard sample. The treatments were prepared with 40, 50 and 60 per cent of debittered palmyra tuber flour as T_1, T_2 and T_3, respectively.

Crackers are thin, lightweight, crispy baked snacks. The crackers were prepared by using a method suggested by Giannottos et al. (2023) with modifications. Crackers with 100 per cent wheat flour served as the standard. The treatmentswere prepared with 40, 50 and 60 per cent of debittered palmyra tuber flour as T_1, T_2 and T_3 respectively.

Soup sticks or breadsticks are long, pencil-sized, crispy, dry-textured bread. These sticks are used along with appetisers like soups to enhance the palatability. For preparing soup, a method described by CFTRI (2021) was followed with slight modifications. The treatments were prepared with 20, 25 and 30 per cent of debittered palmyra tuber flour as T_1, T_2 and T_3, respectively.

Chocolate is a sweet made from dried cocoa beans through a series of processes. It is one of the most popular snacks in the world and has high acceptability among all age groups. Dark chocolate was used as the base for the preparation of chocolate owing to its nutritional benefits. Three treatmentsof chocolate were prepared with 15, 20 and 25 per cent of debittered palmyra tuber flour as T_1, T_2 and T_3, respectively.

Sensory evaluation of the value-added food products

The sensory evaluation was performed using a nine-point hedonic rating scale to understand the organoleptic characteristics of the formulated value-added food products. The nine-point hedonic scale scorecard was designed with reference to Srilakshmi (2023), and the formulated food products were scored by 20 semi-trained panellists at a scale ranging from one (dislike extremely) to nine (like extremely).

Statistical analysis

The results of the sensory analysis were subjected to descriptive statistics and one-way ANOVA using SPSS 21. The best selected version with the highest sensory scores was then evaluated for nutritional composition, physical characteristics and shelf-life evaluation.

Nutrient composition

The best selected treatments of the formulated value-added food products were analysed for energy, carbohydrates, proteins, fats, fibre, calcium and iron.

Texture and pH analysis

Texture analysis was done to evaluate the hardness of the samples using Texture Analyser (TA-TX2i, Stable Micro Systems, Godalming, UK. The pH (Potential of Hydrogen) of the samples was calculated by crushing or melting one gram of the sample in distilled water, followed by filtering the water. The pH was determined using a digital pH meter after calibration with standard buffers of four and seven (Dias et al., 2019).

Shelf-lifeevaluation

The value-added products were further studied for the shelf life using the direct method, which involves real-time storage and testing the product until it fails to meet the sensory characteristics. The products were stored in a sterilised condition. Murukku, biscuits, crackers and soup sticks were stored in airtight containers while chocolates were wrapped in aluminium foil and stored in a refrigerator at four degrees Celsius, at room temperature and were observed for changes in sensory characteristics.

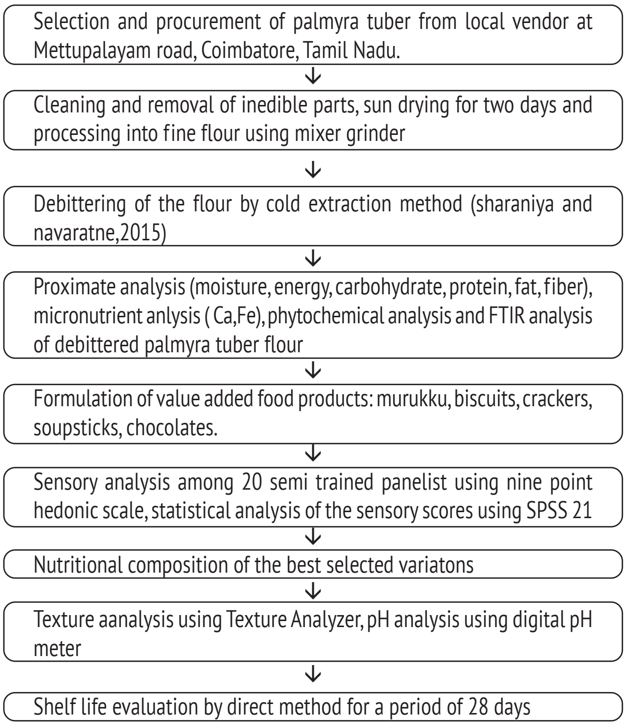

Figure 1. Process flow diagram for the development and evaluation of value-added food products from palmyra tuber flour

Results and discussion

Description of palmyra tuber

The palmyra tuber (*Borassus flabellifer* L) belongs to the family *Aceraceae*. The tuber was observed to be a brown, elongated tuber with tapered ends. One tuber weighs between 60 and 65g, and the length varies between 25 and 30 cm. The texture of the tuber is fibrous. Saravana and Kavitha (2017) reported similar results.

Quantification of palmyra tuber flour.

The palmyra tuber was procured fresh and processed into fine flour. From 5,200g of fresh tuber, 4,800g remained after removal of inedible parts. After drying, the weight reduced to 3,316g and further to 2,996g, reflecting a significant loss of moisture during the drying process. The yield of flour from fresh tuber was 62.4 per cent. This yield indicates that to obtain 100 grams of palmyra tuber flour, 174 grams of fresh tuber are required. Calculating yield percentage helps determine the amount of raw material needed for production.

Nutrient content of debittered palmyra tuber flour

Palmyra tuber is an underutilised agricultural crop with high nutritional value and notable nutraceutical potential. However, the use of its processed flour is limited due to its characteristic bitter taste. In the present study, the flour was subjected to a debittering process and a subsequent nutrient analysis was conducted on the debittered palmyra tuber flour. The results of nutrient analysis are given below in Table 2

Table 2. Nutrient composition of debittered palmyra tuber flour (per 100 g).

Macronutrients	Analysed Value(100 g)
Moisture (%)	10.9
Energy (kcal)	355
Carbohydrates(g)	83
Proteins (g)	5.74
Fats (g)	<0.1
Fibre (g)	7.71
Micronutrients	
Iron (mg)	7.92
Calcium (mg)	29.1

The flour showed high carbohydrate and dietary fibre content, with appreciable levels of protein, iron, and calcium, and negligible fat content.

The results of nutrient analysis of the palmyra tuber flour, as depicted in Table 2, project the moisture, carbohydrates, proteins, fats, fibre, iron and calcium on a dry weight basis. The carbohydrate content is high, which contributes to the high energy content of the flour. The protein content of debittered palmyra tuber flour is found to be moderate when compared to legumes and grains. The fat content is significantly less. The amount of fibre present is 7.71 grams, which is relatively higher as per FSSAI (2018). 6 grams of fibre per 100 grams of solids is considered high or rich. The calcium content is relatively low. However, the iron content of the tuber flour is relatively high and can be compared to terrestrial plants. Similar results were reported by Perumal et al. (2018).

Phytochemical screening of palmyra tuber flour

Phytochemicals are bioactive compounds present in plant materials that are known to exhibit functional properties such as antibacterial, anticancer, antioxidant, and anti-inflammatory activities; hence, their identification is important (Agi dew, 2022). The phytochemical screening of palmyra tuber flour was performed using standard qualitative tests.The presence of alkaloids, flavonoids, phenolic compounds, and anthraquinones was confirmed using Mayer's reagent, the alkaline reagent test, the ferric chloride test, and Borntrager's test, respectively. The presence of these compounds suggests that the native tuber may possess various health benefits, including antioxidant, anti-inflammatory, antimicrobial, antiviral, and anti-allergic effects, which can exhibit therapeutic potential against chronic diseases (Kumar et al., 2023).

Functional groups identified using FTIR spectroscopic analysis in palmyra tuber flour

The sample (debittered palmyra tuber flour), on exposure to the spectroscopy system, shows that the functional groups are identified in the form of a peak ratio at different wavenumbers. The infrared spectrum consists of a range between wavenumbers 4000cm-1 to 400 cm-1. The prominent functional groups observed in the debittered palmyra tuber flour sample are in the range of 3950.22–493.78cm-1. The recorded FTIR spectrum is shown in Fig.2.

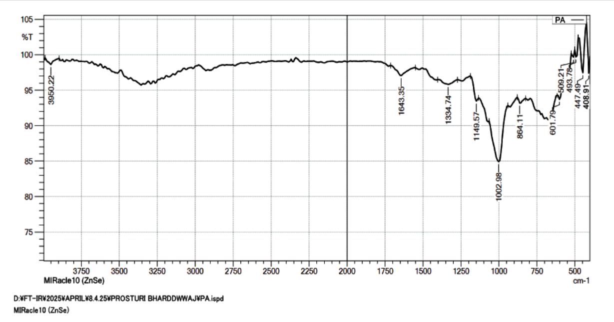

Figure 2. FTIR spectrum of debittered palmyra tuber flourshowing characteristic peaks corresponding to hydroxyl groups, alkenes, phenols, amines, phosphates, alkanes, and halo compounds, indicating the presence of bioactive functional groups with potential antioxidant and antimicrobial properties.

Fig. 2 represents the peaks and corresponding functional groups. The peak observed at 3950.22 cm-1 in the sample was due to the presence of O-H stretching vibrations of hydroxyl groups. The peaks centred at 1643.35 cm-1, cm-1, 1334.74cm-1 1149.57 cm-1 correspond to C=C cyclic alkene, O-H stretching phenols, C-N and C-H stretching amine and alkane. Spectral peaks at 1002.98 cm-1 indicated the presence of a phosphate ion. The peak at 864.11 cm-1 corresponds to C-H stretching of an alkane. Spectral peaks at 601.76 cm-1, 509.21 cm-1 and cm-1 493.78 indicated the presence of C-Br, C-Cl and C-I bonds of halo compounds. A similar functional group was observed by Subrahmanyan et al. (2017). The presence of hydroxyl groups, alkene and phenols is associated with antioxidant activity. These compounds can eliminate free radicals and potentially prevent various diseases. Additionally, they also exhibit anti-inflammatory and anti-microbial properties (Al-Mamary and Moussa, 2021).

Sensory analysis of value-added food products

The results of sensory evaluation are represented in Table 3, depicting the mean sensory scores obtained. All the treatmentsof the formulated value-added food products had attained a minimum mean score of seven points on a point hedonic scale, indicating them as acceptable by the panellists. Yet treatment T_2 of murukku and soup sticks and treatment T_3 of biscuits, crackers and chocolates were found to be the most acceptable of all. To analyse whether the difference between the treatments of each product was significant or not, a one-way ANOVA was done using SPSS 21 Version. The results of one-way ANOVA suggest that there was no statistically significant difference among the treatmentsof formulated value-added food products. However, based on the mean sensory scores' treatment T_2 of murukku with 30 per cent debittered palmyra tuber flour, T_3 of biscuits with 60 per cent debittered palmyra tuber flour, T_3 of crackers with 60 per cent debittered palmyra tuber flour, T_2 of soup sticks with 25 per cent debittered palmyra tuber flour and T_3 of chocolates with 25 per cent debittered palmyra tuber flour was found to be highly acceptable among the other treatments by the panellist.

Table 3: Mean sensory scores of value-added food products prepared using debittered palmyra tuber flour.

Treatments	Appearance	Color	Taste	Texture	After-taste	Overall Acceptability
			Murukku			
STD	8.10	7.70	7.90	8.00	8.20	8.00
T_1	8.30	7.40	7.70	7.80	7.90	7.80
T_2	8.10	7.90	7.90	8.40	7.50	8.00
T_3	7.70	7.50	7.70	8.10	7.70	7.60
			Biscuits			
STD	8.30	8.03	8.50	8.05	8.20	8.27
T_1	8.25	8.10	8.60	8.10	8.10	8.23
T_2	8.00	8.00	8.60	8.30	8.20	8.22
T_3	8.25	8.05	8.70	8.35	8.35	8.34
			Crackers			
STD	8.35	8.05	7.90	8.40	7.40	8.02
T_1	8.35	8.05	8.05	8.40	7.40	8.05
T_2	8.20	8.15	8.05	8.40	7.50	8.06
T_3	8.20	8.35	8.20	8.50	7.50	8.15
			Soup sticks			
STD	8.15	8.30	8.20	8.05	7.95	8.16
T_1	8.20	8.05	8.00	8.10	7.90	8.05
T_2	8.15	8.20	8.35	8.30	8.25	8.21
T_3	8.25	8.20	8.25	8.20	8.05	8.19
			Chocolates			
T_1	9.00	9.00	8.00	9.00	8.50	8.70
T_2	9.00	9.00	8.15	9.00	8.55	8.75
T_3	9.00	9.00	8.20	9.00	8.65	8.77

STD: Standard; T_1: Treatment 1; T_2: Treatment 2; T_3: Treatment 3
Scores for appearance, colour, taste, texture, aftertaste, and overall acceptability were evaluated using a 9-point hedonic scale by 20 semi-trained panellists. STD refers to the standard/control formulation, while T_1, T_2, and T_3represent different test formulations.

Nutrient composition of the selected treatments of the formulated value-added food products.

The nutritive values of the formulated value-added food products are presented in Table 4. The data show that all products are enriched with protein, fibre, iron, and calcium. Protein content ranged from 8.0 g/100g in soup sticks to 14.0 g/100g in biscuits, meeting a minimum of 10 per cent of the Recommended Dietary Allowance (RDA) for protein across all age groups. Fibre content was notably high, ranging from 5.16 to 10.1 g/100g, meeting the criteria for "high fibre" foods as per FSSAI guidelines (2018). Iron content ranged from 3.96 mg to 10.7 mg/100g, while calcium ranged from 32.96 to 101.5 mg/100g, with chocolates and soup sticks showing the highest values, respectively. The overall

Table 4. Nutrient composition of formulated value-added food products containing varying percentages of debittered palmyra tuber flour (DPTF).

Nutrients	Value Added Food Products				
	Murukkus 30% DPTF	Biscuits 60% DPTF	Crackers 60% DPTF	Soup sticks 25% DPTF	Chocolates 25% PTF
Energy (Kcal)	710	533	356	299	515
Carbohydrate (g)	54	85	65	55	60
Protein (g)	8.45	14	11	8	10
Fat (g)	50	17	5.8	5	25
Fibre (g)	5.16	8	8	8	10.1
Iron (mg)	3.96	6.5	6.4	4.5	10.7
Calcium (mg)	32.96	66	58.5	101.5	72

nutritional profile of these products indicates the potential of debittered palmyra tuber flour as a functional ingredient suitable for dietary supplementation in various health conditions and public health concerns, such as malnutrition (due to its energy and protein content) and anaemia (due to high iron content).

Textural characteristics and pH of the value-added food products

The textural hardness and pH value of the value-added food products are given in Table 5. The instrumental values for hardness aligned well with sensory feedback on product crispness and mouthfeel. For murukku, crackers and biscuits, the texture is expected to be hard, crispy or crunchy, which is reflected in the obtained values. Similar results were obtained by Saranga et al. (2015) for murukku, Singh et al. (2015) for high protein and fibre biscuits and Qadri et al. (2018) for crackers. While for chocolate, the texture is desired to be smooth and melt in the mouth with a low hardness value, as found in the study. However, for soup sticks, the obtained hardness value was found to be poor, indicating a lack of crunchiness, and this can be attributed to excess gluten formation. For pH, all the formulated value-added food products demonstrated to be slightly acidic.

Table 5. Hardness and pH values of different value-added food products

Value Added Food Products	Hardness(N)[a]	pH[b]
Murukku	1417.50	5.10
Biscuits	437.70	5.53
Crackers	466.20	5.53
Soup sticks	87.56	6.00
Chocolates	27.67	6.5

[a] Hardness expressed as force required to break the product (Newton).
[b] pH measured in aqueous extract of the product.

Shelf-life evaluation

The shelf life of the formulated value-added food products was assessed using direct sensory evaluation over a 28-day period under ambient storage conditions (25 ± 2°C) in sealed, food-grade packaging. Sensory parameters, including appearance, taste, texture and aftertaste, were evaluated at seven days interval (days 0, 7, 14, 21, and 28). Murukku, biscuits, crackers, and chocolates maintained stable sensory attributes throughout the 28-day period, with no noticeable changes reported. However, soup sticks exhibited slight changes in texture beginning on the 14th day, suggesting a gradual loss of crispness, possibly due to moisture uptake or gluten-related structural changes. Overall, the products remained sensorially acceptable for up to 28 days, indicating good shelf stability under the given conditions. Furthermore, shelf life can be more precisely determined through the inclusion of additional methods such as microbial analysis and physicochemical testing. Incorporating these parameters in future studies would provide a more comprehensive and reliable assessment of product stability and safety.

Conclusion

The palmyra tuber is an underutilised indigenous food that possesses numerous nutritional and therapeutic benefits. The utilisation of the tuber is limited to its traditional consumption technique of either boiling or roasting. The use is limited in processed form due to its characteristic bitter taste. Research has previously shown that the incorporation of the tuber flour increases the nutritional profile and bioactive compounds. The flour is also incorporated as a thickening agent. In this study, the processed flour was debittered and analysed for nutritional and phytochemical content. Functional groups were identified through FTIR spectrometry. The results demonstrated the tuber to be a good source of proteins, fibre, iron and calcium, exhibiting prominent phytochemicals and functional groups. The tuber was incorporated into five products, and it was observed that the best acceptable level was 30 per cent for murukku, 25 per cent for soup sticks and chocolates, and 60 per cent for biscuits and crackers.The products exhibited slightly acidic pH, and the textural characteristics were appreciable for most of the products. The products were stable for 28 days except for soup sticks. Therefore, these findings underscore the potential of underutilised resources like the palmyra tuber in developing value-added foods, contributing to dietary diversification, sustainable food innovation and improved public health.

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