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Research Article

Shelf-life extension of tender endosperm of Palmyra palm (*Borassus flabellifer*) through retort processing

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Abstract
There is a demand for Palmyra palm (*Borassus flabellifer*) tender endosperm (Taal; Nungu) in the off season due to its health benefits. To extend the shelf life of Palmyra palm Tender Fruit Endosperm (PTFE) it was thermally processed. The versatile retort processing technology was used to increase the shelf life. Processed tender endosperm packed in transparent retort pouches (TRP) and nontransparent retort pouches (NTRP) were evaluated for textural, color, microbial, and sensorial properties. Heat penetration tests and F- values were also determined. Processed tender endosperm was compared with fresh endosperm and there was a shelf life of 6 months under ambient storage conditions (30-32°C). The process time to reach lethality in nontransparent pouches (14.03 min) was higher than that in transparent pouches (13.02 min) and the difference may be due to the layer addition of packaging material. Textural profile analysis revealed that hardness, gumminess, and chewiness decreased when the processing and storage time was increased. The sensory score obtained similar results to the textural analysis (Hardness value of TRP:5.063kgfand NTRP: 4.58kgf); succulence and toughness decreased over the prolonged processing time. The tender endosperm in metalized retort pouches scored higher (7.9 as overall acceptability) than that in transparent retort pouches (7.8 as overall acceptability) in terms of sensory analysis. Retorted pouches were microbiologically safe until 6 months with the absence of *Clostridium, Staphylococcus and Salmonella spp.*The present experiment on shelf life extension of Palmyra tender endosperm (Nungu) helps in preserving the perishable healthy delicacy for more months and also enables to fetch higher income for the farmers with minimal investment.

Keywords: *Borassus flabellifer*, Palmyra palm, Retort processing shelf life, Thermal treatment

INTRODUCTION

The *Borassus flabellifer* Linn (Palmyra palm) is distributed along the coastlines and in thegroves of western and eastern parts of India, especially where tropical weather exists. *B. flabellifer* L., an ecologically important crop in India, belongs to the family Arecaceae (Jerry, 2018), commonly known as the Asian toddy palm. Palm trees are deeply embedded in local cultures and naturalized throughout India (Prance and Nesbitt, 2012), especially Tamil Nadu. Immature fruit is locally called Nungu and is removed when the fruit endosperm is sweetish in taste and jelly-like consistency, which is highly perishable and seasonal. Retort processing is an economically viable technology with fast cooking times(Bassett and Dolan 2020) that has al-ready proven its stand in the market when people are poignant about quality and health. This experiment aimed to extend the shelf life of Palmyra tender endosperm by applying thermal processes such as retort processing. Increasing storage life by introducing simple, adaptable technology generates more income directly and indirectly for Palmyra palm producers. This also invites curious agripreneurs to perforate into this thermal processing of this delicacy item for daily consumption and helps in the export avocation.

MATERIALS AND METHODS

Freshly harvested Palmyra Palm Tender Fruit Endosperm (PTFE) were sorted for uniform size and procured with full whitish peel from the Alamathi area, Tiruvallur district, Tamil Nadu. Peeled PTFE was studied in two types of retort pouches: transparent retort pouches (TRP) and (NTRP) nontransparent pouches.

Sugar concentration was optimized based on the sensory map and preference map using the consumers' data by running principal component analysis (PCA). Four different concentrations of sugar strengths (T1=40° Bx, T2=45 ° Bx, T3=50 ° Bx, and T4=55 ° Bx) were added along with tender endosperm at a filling ratio of 2:3 in pouches with dimensions of 200 mm ×150 mm of 300 g capacity with a thickness of 110 microns and sealed. The mass to syrup ratio was calculated based on a linear regression model (Mathanghi*et al*., 2020).

The 9-point hedonic scale test was used for sensory evaluation of food products (Bhalerao *et al.,* 2020).The pouches of transparent and nontransparent retorts were opened and tested for their color and appearance, sweetness, taste, succulence, toughness, and overall acceptance by 20 semitrained panelists from the institute.

Using hedonic scale values, a sensory map was outlined using a PCA biplot; Agglomerative Hierarchical Clustering (AHC) was framed to group the panelist. Consumers were clustered depending on their preference for sugar concentrations based on sensory explanatory parameters such as color, flavor, taste, texture and overall consumer acceptability. Then,the PREFMAP method was used for the final selection of appropriate sugar strength liked by the panelist. PREFMAP is a useful tool for understanding the hierarchical or order of preference structure among the treatments and the proclivity of consumer acceptance (Pestorić *et al.,* 2017; Miquelim *et al*., 2008)

Thermal process evaluation of retort PTFE

A water spray type of retort (manufactured by Lakshmi Engineering Pvt. Ltd) was used in this study. The freshly harvested tender endosperm of Palmyra had a pH of 6.23 ± 0.17, and the water activity was found to be 0.924±0.03. This range of values was considered a low acid food category and protocol was used for low acid food (Muzzalupo, 2013). For conducting heat penetration studies, both types of pouches were fitted with a thermocouple to record the product core temperatures. Both TRP and NTRP were thermally processed at a temperature of 121.1°C with a Z value of 10°C, whereas the Cook Value (CV) constants were considered at temperature of 100°C with a Z value of 33°C (Stumbo, 2013). The cook value measures nutrient degradation temperature; in other words, the extent of cooking and nutritional loss during processing was analogous to the D value (Ling*et al*., 2015; Singh *et al., 2015*).

Thermal process time was calculated using the trapezoidal integration method by determining the lethality value for every temperature measure, then adding that lethality value together and then multiplying by the time interval in minutes suggested in (Safe food *360,* 2014). After processing the product, it was immediately cooled using ice-cold water, wiped off the wet surface, and labeled for storage purposes.

Texture analysis retort processed PTFE

Texture profile analysis was performed using a Texture Analyser instrument TA.XT Plus analyser from Stable Micro Systems, UK. It was studied by cutting a rectangular sample with an approximate dimension of 2 × 2 × 1.5 cm (Rahman & Al-Farsi, 2005) and was ascertained using a TPA cylindrical probe of a 75 mm compression platen. TA. An XT Plus texture analyser was set with a test speed of 5.00 mm/sec, a distance of 10.00 mm was given, and strain was fixed at 75.0 percent, wherein the autotrigger type was set with a trigger force of 5.0 g. Primary TPA parameters, such as hardness, springiness, cohesiveness, and resilience, and secondary attributes, such as adhesiveness, gumminess, and chewiness, were ascertained for six replicates. Force-by-time data from each test were used to calculate the mean values for the TPA parameters as described by Singh *et al* (2013).

Color analysis of processed PTFE

Measurement of color in retort processed samples was carried out using a Spectrocolorimeter (Colorflex EZ, Hunter Associates Laboratory, Inc, Reston, VA) using white reference tiles. The degree of lightness (L*), degree of redness (+ve a*) or greenness (-ve a*), degree of yellowness (+ve b*) or blueness (-ve b*) values were obtained from the equipment, and the average value was taken.A comparison was made with each sample at different times of storage. Hue, chroma values, and color coordinates were obtained from L, a*, b* values by using the following formulae (García-Toledo *et al*., 2016)

Hue = $\tan^{-1}(b^*/a^*)$ ..Eq. 1

Chroma = $(a^2 + b^2)^{-½}$ ..Eq. 2

Color coordinate = a/b ..Eq.3

Proximate analysis and physicochemical characterization of retort processed PTFE

The moisture percentage was calculated using the hot air oven method, and the crude protein content was calculated using the micro–Kjeldahl method. Ash content was determined using a muffle furnace. Total fibre content was determined using afibrotron (Tulinequipment), and total fat was determined using asoxtron from Tulinequipment (Latimer & Association of Official Analytical Chemists International, 2019). TSS was measured using an Erma hand refractometer, and pH was measured using a (MP-1 PLUS, Susima Technologies) pH meter calibrated with a buffer solution of pH 4.0 and 7.0.The TSS of freshly harvested PTFE was 8.5 °Bx with a titrable acidity of 0.62 %. The viscosity of the sugar syrup wasanalyzed during various time intervals of storage using a Cole-Parmer rotational viscometer with spindle number L1. It was measured at 32-34°C, and the purity of sugar used for syrup preparation was 99%.

Microbial analysis of retort processed samples

The enumeration of total viable count was performed by the SPC method, and the results were expressed as CFU/g of the sample. *Staphylococcus, Salmonella, and Coliforms* were enumerated using standard protocols (Shiningeni *et al*. 2019). The incubation of retort pouch samples was performed at two different simulated temperatures (35°C for 10 days; 55°C for 5 days) to ensure commercial sterility. Randomly chosen TRP and NTRP (in triplicate) were kept for the test. After incubation for stipulated time, pouches were opened under aseptic conditions, homogenized, done with serial dilutions, inoculated in Robert cooked medium broth, kept airtight using an anaerobic chamber (Pahalagedara *et al*., 2020)and tested for *Clostridium species* (Van Schothorst *et al*., 2009; Awad *et al.,* 2014).

Data analysis

The IBM SPSS statistical package for Windows, version XX (IBM Corp., Armonk, N.Y., USA), was used for the analysis of the experimental results. Preference mapping was used as a decision tool, where configuration analysis based on principal component analysis was performed using XLSTAT 2021.1 (Addinsoft, Long Island, NY, USA) software to determine the sugar strength.

RESULTS AND DISCUSSION

Sugar strength optimization to use as a medium for retorting PTFE

Twenty data on consumer preferences were grouped into homogenous to make it convenient for interpretation obtained from Agglomerative Hierarchical Clustering . Then, class centroids were grouped into five clusters with increasing order of preference. Dendrogram output and PREFMAP contour are displayed in Fig.1a, b. Based on the output; T4 was not liked by clusters 2, 4, and 5. T1 was also not liked by clusters 1, 3, and 5. T3 was the least preferred by all clusters, and finally, T2 was given the most preference by all clusters, especially clusters 1, 2, and 5.T2, i.e., 45°Bx sugar concentration, was chosen as the medium concentration for PTFE for further studies.

Thermal processing studies of retort PTFE

Thermal processing studies showed lethality values for NTRP and TRP pouches of 14.03 minutes and 13.02 minutes, respectively, and heat penetration graphs are given in Fig. 2.a and 2.b.The total process time of 43 minutes was sufficient to reach commercially sterile products. From the graph, core temperature values and corresponding retort temperatures can be ascertained. The cook value for NTRP was 186.33°C, and TRP was

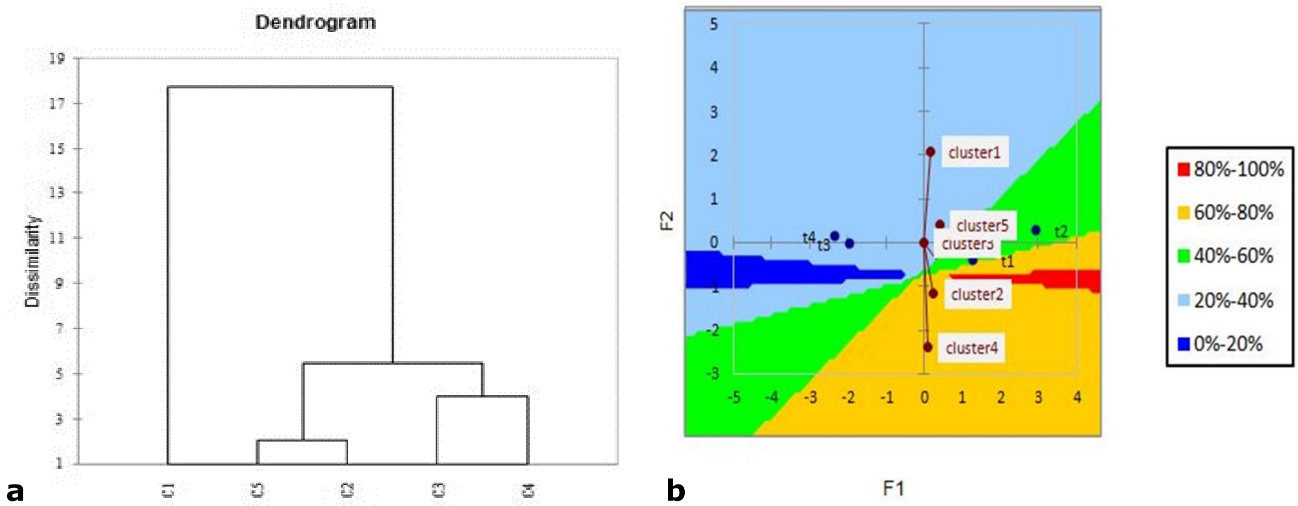

Fig. 1. a) *Dendrogram showing clusters corresponding to treatments (t1: 40° Bx, t2: 45°Bx, t3:50°Bx, and t4: 55°Bx);* **b)** *Contour and preference map*

178.74°C to attain lethality and increase the shelf life.

Texture Profile analysis of retort processed PTFE

TPA analysis showed that the hardness of retorted PTFE was increased when compared with fresh PTFE (Fig.3). This may be due to the oozing of fruit sap and reduced fineness of the tissues during the sterilization process. Raw PTFE had a hardness of 5.46kgf, while retort processed products had 4.585 kgf (NTRP) and 5.063kgf (TRP). The springiness of fresh endosperm, TRP, and NTRP were 0.745 mm, 0.817 mm and 0.832 mm, respectively. Fresh PTFE had 0.588±0.01 cohesiveness, PTFE kept in transparent retort pouches had acohesion value of 0.624±0.01, and PTFE kept in non-transparent pouches had a cohesion value of 0.707±0.02. The gumminess recorded was 3.295±0.04 (fresh), 2.863±0.02 (TRP) and 2.104±0.11 (NTRP). Chewiness, the consistency appropriate for swallowing for PTFE was recorded as1.286 ±0.03 kgf.mm for fresh sample, 2.338±0.06 kgf mm for TRP, and 2.455±0.03 kgf.mm for NTRP sample. After heat processing, PTFE decreased the pouch hardness and gumminess and increased the proportional springiness and cohesiveness. A similar trend in texture analysis was observed by Mathanghi *et al*., (2021) in the canning of Palmyra palm Tender Fruit endosperm; while canning, it was sorted based on weight for convenient handling, but the stage of the endosperm also counts on the texture profile. Slightly matured endosperms have an innate rubbery texture when compared to tender endosperm.

Color analysis of retort processed PTFE

Color analysis showed that the L* values were 44.54, 36.61, and 36.29 for fresh, TRP and NTRP, respectively. Fig. 4 shows that there was a decreasing trend for L* and hue angle (in comparison with fresh PTFE), whereas increasing trends were observed for chroma and coordinates. This may be due to violet–red discolouration of PTFE due to the presence of specks of whitish skin layer that affects the color value a*. Leucoanthocyanidin in peels leads to pink discolouration due to oxidation reactions (Chamchong *et al*., 2016). When the pH of the sugar solution was lowered, red anthocyanidin was acquired from the whitish peel of the tender endosperm. During optimization of sugar strength as a syrup addition, at 55° bx, visible red discolouration occurred in retort PTFE with the presence of more specks of an unpeeled whitish layer; this condition may be due to an increased acidity level. However, the addition of alkaline salt to 0.2% (either added intentionally or through the usage of tap water) would inhibit the polyphenol oxidase enzyme in canned lychee, but it would result in abnormal taste and pale color (Somseang, 2007). In this study, sugar solutions were prepared from RO-treated water resulted in a meager color change with careful removal of almost all whitish peels

Table 1. Proximate analysis and physico-chemical characterization of retort processed Palmyra palm Tender Fruit Endosperm over real-time storage

	Fresh PTFE	Transparent Retort Pouch PTFE					Non-Transparent Retort Pouch PTFE				
		0^{th}d	60^{th}d	120^{th}d	180^{th}d	F value	0^{th}d	60^{th}d	120^{th}d	180^{th}d	F Value
Proximate parameters (g/100 g)											
Moisture	87.09±2.32	85.69±2.5	75.49±2.88	71.58±1.8	66.76±1.22	68.64**	84.89±1.02	74.88±2.32	72.03±3.1	65.82±3.2	64.68**
Protein	0.9±0.02	0.88±0.02	0.85±0.04	0.83±0.02	0.91±0.01	2.92^{NS}	0.81±0.01	0.83±0.04	0.89±0.01	0.88±0.02	6.39**
Crude fibre	0.80±0.05	0.80±0.05	0.81±0.07	0.82±0.001	0.84±0.01	0.957^{NS}	0.78±0.01	0.77±0.04	0.82±0.02	0.88±0.02	9.18**
Fat	0.08±0.001	0.08±0.004	0.09±0.01	0.08±0.001	0.09±0.001	1.66^{NS}	0.09±0.004	0.09±0.001	0.08±0.01	0.08±0.01	1.51^{NS}
Ash	1.0±0.22	1.08±0.16	1.01±0.02	1.14±0.01	1.17±0.21	0.814^{NS}	1.01±0.03	1.02±0.04	1.08±0.04	1.13±0.13	1.32^{NS}
Physicochemical Parameters											
TSS of PTFE (°Bx)	8.23±0.49	8.58±0.18	10.48±0.09	11.3±0.03	14.85±0.39	782.38**	9.09±0.07	10.76±0.29	12.08±0.07	15.21±0.35	771.22**
pH of PTFE	5.8±0.58	6.4±0.1	6.2±0.1	5.89±0.13	4.81±0.1	296.38**	6.44±0.1	6.1±0.12	5.18±0.13	4.33±0.08	494.85**
Viscosity of sugar syrup (cp)	Nil	6.46±0.12	5.95±0.05	5.49±0.12	4.83±0.15	231.08**	6.38±0.16	5.93±0.13	5.49±011	5.06±0.05	215.0**

Data are mean±SD (n=6);d- days

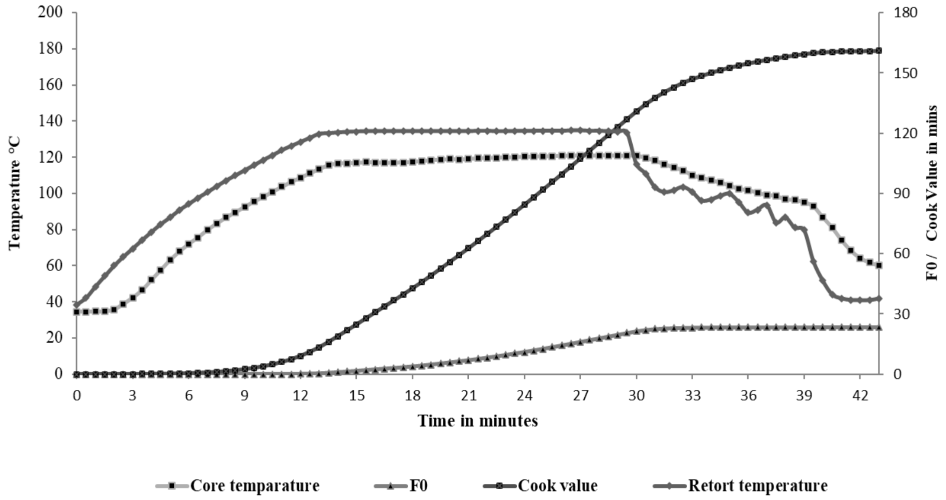

Fig. 2a. *Heat penetration characteristics, cook value, and F0 value of transparent retort pouch Palmyra palm tender fruiteEndosperm*

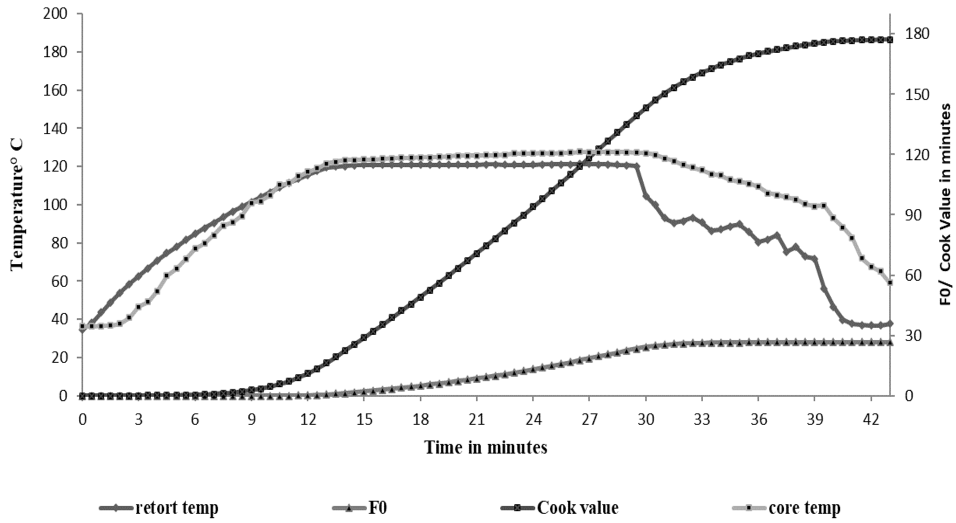

Fig. 2.b. *Heat penetration characteristics, cook value, and F0 value of nontransparent retort pouch Palmyra tender fruite Endosperm*

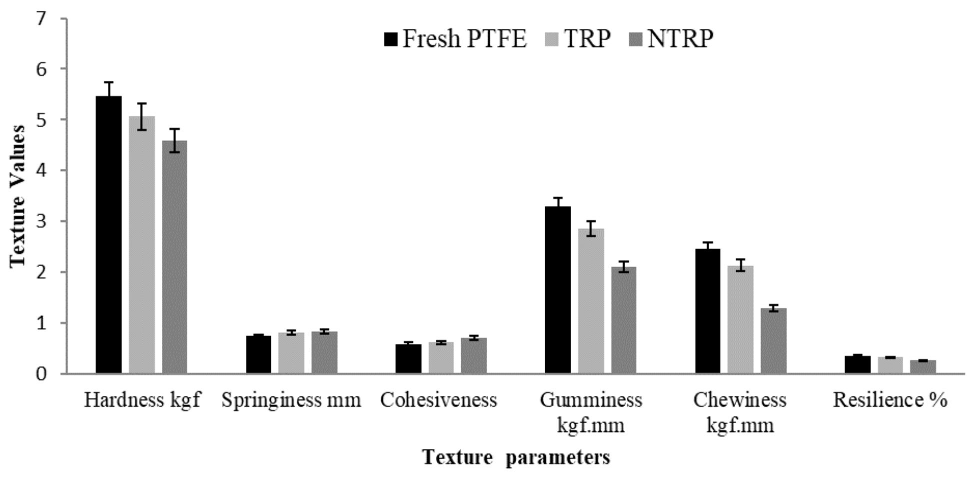

Fig. 3. *Textural analysis of fresh and retort processed Palmyra palm tender fruit endosperm. TRP: Transparent retort pouch; NTRP: Non-transparent retort pouch*

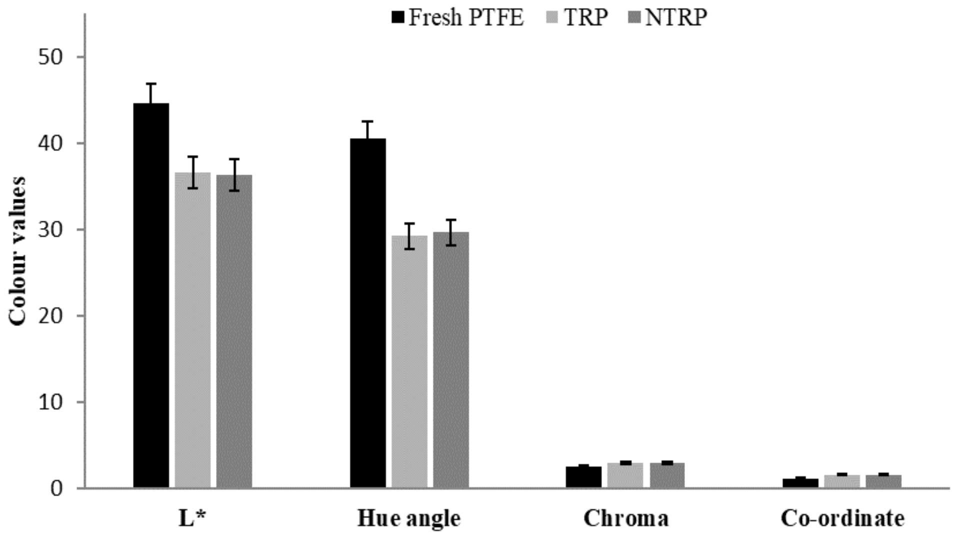

Fig. 4 *Color analysis of fresh and retort processed Palmyra palm tender fruit endosperm*

was performed.

Sensory evaluation of retort processed PTFE

Sensory analysis is a significant tool in market launching, marketing decisions, pricing and product positioning and makes it important to study throughout the storage period (Iannario *et al.*, 2012). Organoleptic analysis conducted by panelists (Fig. 5) gave scores for color and appearance of 8.25 for fresh fruits, 7.55 for TRP and 8 for NTRP. The reduction in color score may be due to discolourations. Prolonged heat treatment will have an impact on the color of the Palmyra pal tender fruit endosperm. A similar observation of a reduction in colour values was observed by Catauro and Perchonok (2012) in retort processed carrots, sugar snaps peas and apricot cobbler, where there was a substantial decline of colour values upto 20 %. This was attributed to increased a* values and decreased L* values. Regarding sweetness, it was less obvious in thermally processed endosperm due to the immersion of tender endosperm into sugar solutions. The succulence of PTFE was reduced when compared with fresh samples, which may be due to oozing of fruit sap from tender endosperm; additionally, the toughness was reduced from 8.5 in fresh samples to 7.55 in TRP samples and 7.6 in NTRP samples. This may be due to cooking PTFE at higher pressure condition and increased temperature. Chiang and Luo (2007) stated that increased pressurized cooking reduced the toughness of lotus root products by impacting the cellulose and lignin contents and consequently altered the texture. Subjective scores of sensory evaluations coincide with TPA analysis using an instrumental texture analyzer. The overall acceptability score of processed PTFE samples was comparable (TRP-7.8 and NTRP-7.9) with fresh PTFE (8.0).

Real-time storage analysis of retort processed PTFE

Retorted pouches were kept at ambient temperatures (30-32°C) for 6 months of storage. The moisture content gradually decreased from the0^{th} day of heat processing to 6 months in both types of packaging. This may be due to osmotic dehydration. The food-to-mass ratio, sugar solution concentration, and heat applied were the influencing factors for osmosis that occurred throughout storage as reported by Ramya and Jain (2017). There was little difference in other proximate parameters, such as protein, fat, ash, and fiber (Table 1). T.S.S on the first day of storage was 8.58±0.18 °Bx (TRP) and 9.09±0.07 °Bx (NTRP), and it gradually continued to increase until the final analysis and showed a significant difference at a p-value <0.01. On the 180^{th} day,the TSS was 14.85±0.39 °Bx (TRP) and 15.21±0.35 °Bx (NTRP). The pH was also steadily reduced from 6.4 to 4.81 in TRP and 6.44 to 4.33 in NTRP. This phenomenon may be due to impregnation of sugar molecules. Discharge of fruit liquid from tissues to syrup would have reduced the viscosity value from 6.46±0.12 to 4.83±0.15 (TRP) and 6.38±0.16 to 5.06±0.05 (NTRP).

Microbial analysis of retort processed PTFE

Commercial sterility encodes the ability of the product to be shelf-stable and devoid of organisms that are viable to cause health issues and are capable of reducing the final quality of the produce (Membré and van Zuijlen, 2011).The commercial sterility test results showed that the heat-processed PTFE was safe until 6 months of storage. Microbiological analysis of retort processed ready-to-eat (RTE) soy-peas curry studied by Abhishek *et al.* (2014) indicated that retort processing achieved commercial sterility for 9 months.

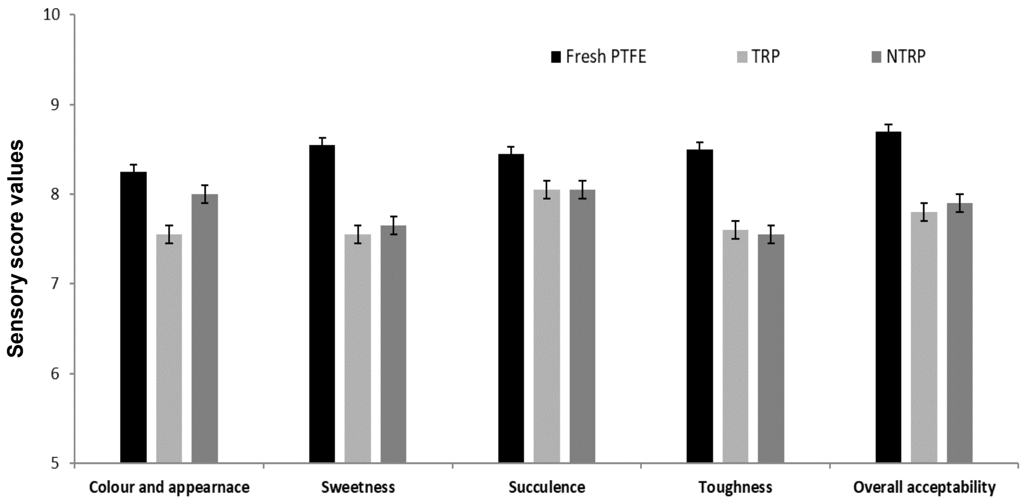

Fig. 5. *Sensory analysis of fresh and retort processed Palmyra palm tender fruit endosperm*

Tests for TPC, *Salmonella*, *Clostridium,* and *Staphylococcus performed* in the PTFE samples every 30 days of a time interval showed that total viable counts increased from $4×10^3$ to $5×10^3$ CFU/g on the 60th day but started reducing from the 120th day ($4×10^3$) to the 180th day ($4×10^2$). Pal *et al.,* (2019) stated that there was an increase in TPC in retort processed *chhenapoda* kept under both refrigerated and ambient temperatures. The absence of *Salmonella, Staphylococcus, and Clostridium* guarantees product safety for up to 6 months of storage and consumption in tropical weather. Similar results were observed by Rajan *et al.* (2014) in retort processed *Chettinad* chicken curry and showed a complete absence of Salmonella spp., Clostridium spp., Staphylococci spp during the entire storage period.

Conclusion

Thermally processed Palmyra palm tender fruit endosperm in convenient retortable pouches was accepted by all age groups of people, and this adaptable technology extended the shelf life of perishable produce to six months of storage. The process time to reach lethality in nontransparent pouches (14.03 min) was higher than that in transparent pouches (13.02 min). The hardness, gumminess, chewiness and resilience of the retort pouches increased, whereas springiness and cohesiveness decreased over prolonged heating.The color values L* and hue angle decreased, whereasthe chroma and coordinate values increased over the heating. The sensory score data showed that the product of non-transparent pouches was preferred by panelists over transparent pouches processed with PTFE in terms of color, appearance, succulence, sweetness and overall acceptability.On processing PTFE, which gives a value addition and crafts an explicit preference for it among consumers, farmers will undeniably grow Palmyra palm trees, which have more veracity in our ecosystem. In the future, this appropriate technology will enhance the remunerative income per rupee of investment for farmers on the standardized retort product.

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Conflict of interest

The authors declare that they have no conflict of interest.

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