Research Article

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Influence of different storage temperatures and packing material in extending shelf life and quality attributes of palmyrah (*Borassus flabellifer* L.) *neera*

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Abstract

Palmyrah *neera* (inflorescence sap) is susceptible to natural fermentation at ambient temperature within a few hours of extraction due to enzymatic and microbial activity. Once fermented, *neera* becomes toddy which is unsuitable as a health drink or as a value-added product. Therefore, a study was carried out to investigate the influence of different packing materials and storage conditions on the shelf life and to keep the quality of palmyrah *neera.* The experiment was conducted in a completely randomised factorial design with two factors at unequal levels replicated thrice. HDPE 50 micron pouch (P_1), PET bottle (P_2) and glass bottle (P_3) and cold storage at 2 °C (S_1), cold storage at 4 °C (S_2) and refrigerated storage (8-10 °C) (S_3) were the packing material and storage conditions respectively used during experimentation. Physio-chemical properties *viz.,* total soluble solids, pH and reducing sugars showed an increasing trend up to the 4th week of storage. At the same time, phenols, titrable acidity and alcohol content increased up to the 6th week of storage. Maximum total soluble solids (10.80 °Brix), reducing sugars (5.76%), minimum phenolic content (0.323 mg) and titrable acidity (1.116%) were recorded when palmyrah *neera* was packed in HDPE 50 micron pouch, whereas the maximum total soluble solids (10.83°Brix), reducing sugars (5.75%), minimum phenolic content (0.322 mg) and titrable acidity (1.14%) were recorded when palmyrah *neera* was stored at 2 °C. Among the different packing material and storage conditions, HDPE 50 micron and storage at 2 °C was effective in extending the shelf life and quality attributes of palmyrah *neera*.

Keywords: *Neera*, packing material, palmyrah, shelf life

Introduction

In India, palmyrah adorns the dry landscape of the semi-arid regions of Tamil Nadu, Andhra Pradesh, Gujarat, Odisha, West Bengal, Bihar, Karnataka and Maharashtra. Currently, the palmyrah palm wealth of India is estimated at 102 million palms, half of which are in Tamil Nadu. Out of 51.9 million palms in Tamil Nadu, more than 50 per cent of palms are concentrated in the southern district of Thoothukudi (Anonymous, 2015).

Among the various edible uses of the palm, the sweet sap (*neera*), obtained by tapping the tip of the male or female inflorescence, is traditionally collected in hanging earthen pots and used to quench thirst (Rao *et al.,* 2021). The sweet sap collected early in the morning is sugary sweet in taste, oyster white, translucent with high nutritive value but susceptible to natural fermentation at ambient temperature within a few hours of extraction since it is rich in sugars, vitamins, proteins and minerals (Vengaiah *et al.,* 2017). Fermented toddy is, in fact, harmful because it is an alcoholic beverage with 5 per cent alcohol hence not recommended as a health drink (Tulashie *et al.,* 2017).

The best method for extending the shelf life and quality of *neera* is to keep the product alive and, at the same time retard the natural enzymatic activity, which can be achieved by cold storage,

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which can retard the activity of microorganisms consisting of bacteria, yeasts and moulds. Low temperature does not destroy these spoiling agents as it does during high temperature but greatly reduces their activities, providing a practical way of preserving *neera* in its natural state. The most important function of any container is to protect the product against any form of loss, damage, deterioration, spoilage or contamination encountered throughout the distribution chain (Verghese *et al.,* 2015). Packaging can also be used to control the availability of oxygen to fruits and vegetables, protect against loss of flavor or fragrance and help products retain their nutritional value (Singh *et al.,* 2021). Proper packaging may protect the product against microbial spoilage from bacteria, yeasts and moulds. It can also protect against microbiological spoilage of stored products.

The palmyrah products were not commercialised as the value addition in palmyrah was not standardised (Rao *et al.,* 2021). Even though palmyrah is an economically important palm, it has not received proper attention from researchers, probably because it is a very slow-growing palm found mostly in the wild state (Vengaiah *et al.,* 2013). In this context, developing value-added products and popularising the same is essential. Hence, there is a need to study the scope of post-harvest techniques for value-added products and their shelf life in palmyrah. Post-harvest treatments, packing material and storage conditions significantly increase shelf life, reduce post-harvest losses and maintain the nutritional quality of *neera* (Sharma *et al.,* 2021). Considering the above, the present investigation was carried out to study the influence of different storage temperatures and packing materials to extend shelf life and quality attributes of palmyrah, reduce the post-harvest losses and maintain the nutritional quality of *neera*.

Material and methods

The present investigation was carried out on the effect of packing material and storage conditions on the shelf life of palmyrah neera during 2019-20 at Postharvest Technology Research Station (PHTRS), Dr. Y.S.R Horticultural University, Venkataramannagudem, West Godavari District, A.P. The location falls under Agro-climatic zone-10, humid, East Coast plain and hills (Krishna-Godavari zone) with an average annual rainfall of 900 mm at an altitude of 34 m (112 feet) above mean sea level. The experimental site was situated at 16° 63' 120" N latitude and 81° 27' 568" E longitude. The experiment was laid out in Factorial with Complete Randomized Design with two factors at unequal levels and replicated thrice. HDPE 50 micron pouch (P_1), PET bottle (P_2), glass bottle (P_3), cold storage at 2 °C (S_1), cold storage at 4 °C (S_2) and refrigerated storage (8-10 °C) (S_3) were the packing material and storage conditions respectively used during the period of experimentation.

Fresh palmyrah palm *neera* was collected from nearby palmyrah palms with the help of *neera* tappers. Initially, the sap was collected in special ice box equipment where the collecting jar surrounded with ice cubes was placed in the thermocol box to maintain a low temperature that can reduce natural enzyme activity and maintains the freshness of *neera*. Later, *neera* was transferred from the ice box to the cold storage unit (PHTRS, Venkataramannagudem) to minimise the fermentation and was used for experimental purposes.

Freshly extracted palmyrah palm *neera* was used for packing. Two hundred millilitres of sap was filled uniformly with 50 units of each packing material, *viz.,* HDPE 50 micron pouch (P_1), PET bottle (P_2) and glass bottle (P_3). Thirty units with each packing material were filled and stored in different storage conditions, *viz*., cold storage at 2 °C (S_1), cold storage at 4 °C (S_2) and refrigerated storage (8-10 °C) (S_3). The samples were analysed for physio-chemical parameters and sensory evaluation at weekly intervals. All the samples were discarded after the 6th week due to the spoilage of neera during the storage period as per the panellist's score for sensory parameters.

Estimation of physico-chemical parameters of palmyrah *neera*

Total soluble solids (TSS) of *neera* were recorded using a digital refractometer at room temperature and expressed in °Brix. Reducing sugars were determined by adopting Lane and Eyon's (1965) method suggested by (Ranganna, 2010). The method described by Ranganna (2010) was adopted to determine titrable acidity. The pH of the sample was tested by taking a direct reading on pH meter model HI 9321 (periodically calibrated with a buffer solution of pH 4.0 and 7.0) according to AOAC (1992). Non-enzymatic browning was estimated according to the method given by Ranganna (2010). Total phenol content was estimated by using the Folin-Ciocalteau reagent (Sadasivam and Manickam, 2005). The alcohol content was estimated based on the formation of green-coloured chromate ions resulting from the treatment of ethanol and sodium dichromate as limiting reactants in the presence of sulfuric acid and acetate buffer (pH 4.3). The absorbance maxima for the ethanol were found 578 nm by the method given by Sumbhate *et al.* (2012). The standard calibration graph of known alcohol concentrations was graphically plotted (R2=0.99) and used to identification of the concentration of alcohol in the samples. All the samples were analysed in triplicates.

Titrable acidity (%) =

$$\frac{\text{Titre value x Normality of alkali x Total volume made up x Equivalent weight of citric acid}}{\text{Aliquot taken for estimation x weight of sample x 1000}} \text{ x } 100$$

Percentage of ethanol in sample = (Cs/Cu) (Au/As) x 100

Where, Cs = Concentration of standard, Cu = Concentration of sample

Au = Absorbance of standard, As = Absorbance of sample

Sensory parameters

The effect of packing material and storage conditions on taste, flavour and overall acceptability of palmyrah *neera* was evaluated by 10 panellists and points were given as per 9-point hedonic scale procedure, as described by Kailayalingam *et al.* (2012-2016). The panellists, free from any addiction related to taste bud damage like wine, tobacco *etc.,* were selected for evaluation. Higher scoring was treated as more acceptable from the taste point of view (Yadav *et al.,* 2014).

The data obtained were analysed statistically using standard methods developed by Panse and Sukhatme (1985) for factorial with Complete Randomized Design (CRD). Statistical significance was tested, using the 'F' value at 5 per cent significance level. The critical difference at the 5 per cent level was worked out for the effects, which were found significant.

Results and discussion

Quality parameters of *neera*

Neera samples, packed and stored under direct packing material and storage conditions were analysed for quality parameters at weekly intervals, and the analysis results are presented in tables 1 and 2.

Total soluble solids (°Brix)

The initial TSS of *neera* was found as 10.00° Brix. The data revealed that the TSS content of *neera* increased during the storage period up to four weeks ranged from 10.00 to 10.90° Brix. Later, a decrease in TSS was noticed on the 5th and 6th week of storage.

The maximum TSS content, *i.e.,* 10.37 to 10.80 and 10.40 to 10.83°Brix, was recorded from 1st to 4th week of storage when *neera* packed in HDPE 50 micron pouch (P_1) and stored in cold storage at 2 °C (S_1). The minimum TSS content, *i.e.,* 10.13 to 10.70 and 10.07 to 10.67°Brix was recorded from 1st to 4th week of storage, respectively, when *neera* packed in glass bottles (P_3) and stored under refrigerated condition (S_3).

The data revealed that the TSS content of *neera* increased during the storage period up to four weeks, and later, a decrease in TSS was noticed on the 5th and 6th week of storage. The decline in TSS can be attributed to the complete hydrolysis of polysachrides and the decline in TSS is predictable as they are the primary substrates of respiration. However, using sugars in respiration and degradation of total soluble substances during storage might be the reason for the decrease in TSS (Kaur *et al.,* 2013). Among the packing material, the maximum TSS content was recorded when *neera* packed in HDPE 50 micron pouch, which might be due to more permeability of gases and lower accumulation of CO_2 leading to low anaerobic respiration rate when compared to PET and glass bottles.

The palmyrah *neera* stored at 2 °C recorded the maximum TSS. This might be due to the slower respiration of substances at low temperatures. Similar findings were reported by Santiago-Urbina *et al.* (2013) and Ramalakshmi *et al.* (2018) in coconut sap.

Table 1. Effect of packing material and storage conditions on physio-chemical properties of palmyrah *neera* during storage

Treatments	TSS (°Brix)						pH						Titrable acidity (%)					
	1st week	2nd week	3rd week	4th week	5th week	6th week	1st week	2nd week	3rd week	4th week	5th week	6th week	1st week	2nd week	3rd week	4th week	5th week	6th week
Packing material																		
(P_1) HDPE 50 Micron	10.37	10.47	10.67	10.80	9.90	8.90	4.32	4.29	4.27	4.27	4.25	4.19	0.665	0.708	0.773	0.858	1.009	1.116
(P_2) PET bottle	10.27	10.33	10.53	10.73	9.50	8.60	4.31	4.28	4.25	4.24	4.23	4.18	0.708	0.794	0.901	0.987	1.095	1.202
(P_3) Glass bottle	10.13	10.20	10.50	10.70	9.73	8.60	4.29	4.24	4.22	4.22	4.20	4.16	0.751	0.816	0.901	1.052	1.159	1.223
LSD (P=0.05)	0.145	0.146	0.149	0.152	0.137	0.123	NS	NS	NS	NS	NS	NS	0.010	0.011	0.012	0.014	0.015	0.017
Storage conditions																		
(S_1) Cold storage @ 2 °C	10.40	10.50	10.70	10.83	9.87	8.83	4.34	4.30	4.28	4.28	4.26	4.20	0.644	0.730	0.816	0.901	1.052	1.138
(S_2) Cold storage @ 4 °C	10.30	10.37	10.53	10.73	9.53	8.73	4.31	4.28	4.26	4.25	4.24	4.19	0.708	0.773	0.837	0.944	1.030	1.138
(S_3) Refrigerated Storage	10.07	10.13	10.47	10.67	9.73	8.53	4.26	4.23	4.20	4.20	4.18	4.15	0.773	0.816	0.923	1.052	1.180	1.266
LSD (P=0.05)	0.145	0.146	0.149	0.152	0.137	0.123	0.061	0.060	0.060	0.060	0.060	NS	0.010	0.011	0.012	0.014	0.015	0.017
Interaction of packing material x Storag 4.28e conditions (P x S)																		
P_1S_1	10.60	10.70	10.80	10.90	10.10	9.00	4.36	4.33	4.30	4.31	4.29	4.23	0.579	0.644	0.773	0.837	0.966	1.095
P_1S_2	10.40	10.50	10.70	10.80	10.00	8.90	4.34	4.3	4.29	4.28	4.27	4.20	0.644	0.708	0.708	0.837	0.966	1.030
P_1S_3	10.10	10.20	10.50	10.70	9.60	8.80	4.26	4.23	4.21	4.21	4.19	4.15	0.773	0.773	0.830	0.901	1.095	1.223
P_2S_1	10.40	10.50	10.60	10.90	9.70	8.80	4.33	4.31	4.29	4.28	4.26	4.19	0.644	0.773	0.837	0.901	1.030	1.095
P_2S_2	10.30	10.40	10.60	10.50	9.10	8.60	4.31	4.28	4.25	4.25	4.24	4.19	0.708	0.773	0.901	0.966	1.030	1.223
P_2S_3	10.10	10.10	10.340	10.80	9.70	8.40	4.28	4.24	4.20	4.20	4.18	4.15	0.773	0.837	0.966	1.095	1.223	1.288
P_3S_1	10.20	10.30	10.70	10.70	9.80	8.70	4.33	4.27	4.24	4.25	4.23	4.17	0.708	0.773	0.837	0.966	1.159	1.223
P_3S_2	10.20	10.20	10.30	10.90	9.50	8.70	4.29	4.25	4.23	4.23	4.21	4.17	0.773	0.837	0.901	1.030	1.095	1.159
P_3S_3	10.00	10.10	10.50	10.50	9.90	8.40	4.25	4.21	4.20	4.19	4.16	4.14	0.773	0.837	0.966	1.159	1.223	1.288
LSD (P=0.05)	NS	NS	NS	NS	0.238	NS	NS	NS	NS	NS	NS	NS	0.017	0.019	0.021	0.024	0.027	0.029

Table 2. Effect of packing material and storage conditions on physio-chemical properties of palmyrah *neera* during storage

Treatments	Reducing sugars (%)						Phenolic content (mg)						Alcohol content (%)					
	1st week	2nd week	3rd week	4th week	5th week	6th week	1st week	2nd week	3rd week	4th week	5th week	6th week	1st week	2nd week	3rd week	4th week	5th week	6th week
Packing material																		
(P_1) HDPE 50 Micron	5.45	5.48	5.57	5.72	5.76	5.69	0.301	0.305	0.312	0.316	0.319	0.323	2.10	2.26	2.59	2.81	3.52	3.87
(P_2) PET bottle	5.32	5.44	5.52	5.65	5.70	5.63	0.307	0.310	0.315	0.321	0.324	0.329	2.12	2.27	2.63	2.83	3.54	3.91
(P_3) Glass bottle	5.22	5.35	5.44	5.56	5.59	5.52	0.310	0.312	0.315	0.317	0.322	0.326	2.14	2.28	2.65	2.90	3.58	4.01
LSD (P=0.05)	0.075	0.077	0.078	0.080	0.080	0.079	0.004	0.004	NS	NS	NS	0.005	NS	NS	0.037	0.040	NS	0.056
Storage conditions																		
(S_1) Cold storage @ 2 ^oC	5.36	5.48	5.55	5.70	5.75	5.68	0.303	0.304	0.310	0.314	0.318	0.322	2.10	2.25	2.59	2.76	3.51	3.85
(S_2) Cold storage @ 4 ^oC	5.27	5.40	5.50	5.62	5.65	5.58	0.304	0.307	0.314	0.317	0.321	0.324	2.11	2.26	2.60	2.81	3.53	3.89
(S_3) Refrigerated Storage	5.35	5.40	5.48	5.61	5.65	5.58	0.311	0.315	0.317	0.324	0.327	0.331	2.15	2.31	2.68	2.96	3.60	4.05
LSD (P=0.05)	0.075	NS	NS	NS	0.080	0.079	0.004	0.004	0.004	0.004	0.005	0.005	0.030	0.032	0.037	0.040	0.050	0.056
Interaction of packing material x Storag 4.28e conditions (P x S)																		
P_1S_1	5.39	5.51	5.58	5.75	5.80	5.73	0.297	0.299	0.308	0.312	0.315	0.318	2.08	2.24	2.56	2.73	3.49	3.77
P_1S_2	5.33	5.45	5.56	5.69	5.74	5.67	0.299	0.302	0.310	0.315	0.318	0.321	2.10	2.25	2.57	2.75	3.50	3.81
P_1S_3	5.63	5.49	5.56	5.71	5.75	5.68	0.308	0.314	0.317	0.321	0.325	0.329	2.14	2.30	2.66	2.95	3.58	4.02
P_2S_1	5.42	5.53	5.59	5.71	5.77	5.70	0.304	0.305	0.309	0.314	0.318	0.322	2.11	2.26	2.59	2.75	3.50	3.83
P_2S_2	5.29	5.41	5.49	5.63	5.66	5.59	0.305	0.308	0.317	0.318	0.321	0.325	2.12	2.26	2.61	2.76	3.52	3.86
P_2S_3	5.25	5.38	5.47	5.61	5.66	5.59	0.312	0.316	0.319	0.331	0.334	0.339	2.14	2.30	2.68	2.96	3.60	4.05
P_3S_1	5.27	5.39	5.48	5.65	5.68	5.61	0.308	0.309	0.313	0.316	0.320	0.326	2.12	2.26	2.62	2.79	3.54	3.95
P_3S_2	5.20	5.34	5.44	5.53	5.55	5.48	0.309	0.312	0.315	0.317	0.323	0.326	2.12	2.27	2.63	2.92	3.56	4.00
P_3S_3	5.18	5.32	5.41	5.50	5.54	5.46	0.312	0.314	0.316	0.319	0.323	0.326	2.17	2.32	2.70	2.98	3.62	4.07
LSD (P=0.05)	**0.130**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.008**	**NS**	**NS**	**NS**	**0.070**	**NS**	**NS**

Potential hydrogen (pH) and titrable acidity

The initial value for pH and titrable acidity of *neera* was found as 4.28 and 0.575 per cent. It was evident from the data that the pH of *neera* decreased during the storage period (4.36 to 4.14), and titrable acidity increased up to six weeks and ranged from 0.579 to 1.288 per cent.

The maximum pH, *i.e.,* 4.32 to 4.19 and 4.34 to 4.20, was recorded from the 1st to 6th week of storage, respectively, in P_1 and S_1. The minimum pH, *i.e.,* 4.29 to 4.16 and 4.26 to 4.15, was recorded from 1st to 6th week of storage, respectively, in P_3 and S_3.

The titrable acidity of a solution is an approximation of the solution's total acidity. An increase in titrable acidity of palmyrah *neera* indicates an increase in acid production (Leena *et al.,* 2021). This may be due to the microbial fermentation of carbohydrates present in the palmyrah *neera*. *Neera* packed in HDPE 50 micron pouch recorded the maximum pH and minimum titrable acidity compared to other packing materials, which might be due to more permeability of gases and lower accumulation of CO_2 leading to low anaerobic respiration rate when compared to PET and glass bottles. The palmyrah *neera* stored in cold storage at 2 °C recorded the maximum pH and minimum titrable acidity (Swami, 2021). This might be due to the slower respiration of substances at low temperatures.

With respect to the above statement, among the packing material, the maximum titrable acidity, *i.e.,* 0.751 to 1.223 and 0.773 to 1.266 per cent was recorded from 1st to 6th week of storage in P_3 and S_3 respectively. The minimum titrable acidity, *i.e.*, 0.665 to 1.116 and 0.644 to 1.138 per cent was recorded from the 1st to 6th week of storage in P_1 and S_1, respectively.

Reducing sugars

The initial values for reducing sugars of *neera* were found as 5.16 per cent. It was evident from the data that the reducing sugars of *neera* increased during the storage period up to five weeks and ranged from 5.18 to 5.80 per cent.

Among the packing material, the maximum increase in reducing sugars, *i.e.,* 5.45 to 5.76 per cent, was recorded from the 1st to 5th week of storage in P_1. The minimum increase in reducing sugars, *i.e.,* 5.22 to 5.59 per cent, was recorded from the 1st to 5th week of storage in P_3.

The maximum reducing sugars, *i.e.,* 5.36 to 5.75 per cent, were observed from 1st to 5th weeks of storage in S_1. On the 2nd, 5th and 6th week of storage, both the treatments, *i.e.,* S_2 and S_3, recorded the same amount of reducing sugars among the storage conditions.

Fresh palmyrah *neera* from the cut inflorescence has sucrose, fructose and glucose, as these are the components of reducing sugars (Hebbar *et al.,* 2018). The sucrose concentration decreased gradually, whereas fructose and glucose increased after the 5th week of storage. This also supports the acid production in the medium and utilisation of sucrose by different microorganisms, including yeast (Ashraf and Hamidi-Esfahani, 2011).

Phenolic content

The initial values for phenolic content of *neera* were found as 0.285 mg. It was evident from the data that the phenolic content of *neera* increased during the storage period up to six weeks and ranged from 0.297 to 0.339 mg. An increase in the phenolic content along the storage period might be due to periodic fermentation of *neera* during storage.

The minimum increase in phenolic content, *i.e.,* 0.301 to 0.323 and 0.303 to 0.322 mg was recorded from 1st to 6th week of storage in P_1 and S_1. The maximum increase in phenolic content, *i.e.,* 0.310, 0.312 and 0.315 mg was recorded at 1st, 2nd, and 3rd weeks of storage respectively in P_3. In contrast, during the 4th, 5th, and 6th weeks of storage, P_2 recorded the maximum increase in phenolic content (0.321, 0.324 and 0.329 mg) among the packing material.

Among storage conditions, the minimum increase in phenolic content, *i.e.,* 0.303 to 0.322 mg, was recorded up to 6th week in S_1. In contrast, the maximum phenolic content, *i.e.,* 0.311 to 0.331 mg, was recorded up to 6th week in S_3.

A gradual increase in the phenolic content during the storage period might be due to periodic fermentation of *neera* during storage (Manikantan *et al.,* 2018).

Table 3. Effect of packing material and storage conditions on sensory parameters of palmyrah *neera* during storage

Treatments	Taste						Flavour						Overall acceptability					
	1st week	2nd week	3rd week	4th week	5th week	6th week	1st week	2nd week	3rd week	4th week	5th week	6th week	1st week	2nd week	3rd week	4th week	5th week	6th week
P_1S_1	8.80	7.90	6.90	5.90	4.80	3.90	8.90	7.80	6.90	5.80	4.80	3.90	8.70	7.80	6.80	5.80	4.70	3.80
P_1S_2	8.70	7.80	6.80	5.80	4.70	3.80	8.70	7.70	6.80	5.70	4.70	3.80	8.60	7.70	6.70	5.70	4.60	3.70
P_1S_3	8.20	7.30	6.20	5.30	4.20	3.20	8.00	7.00	6.00	5.00	4.00	3.20	8.20	7.20	6.20	5.20	4.20	3.30
P_2S_1	8.60	7.70	6.70	5.70	4.60	3.60	8.60	7.50	6.70	5.50	4.60	3.70	8.60	7.50	6.70	5.50	4.60	3.60
P_2S_2	8.50	7.60	6.50	5.60	4.50	3.50	8.40	7.40	6.60	5.40	4.50	3.60	8.50	7.60	6.50	5.60	4.50	3.50
P_2S_3	8.10	7.20	6.10	5.20	4.10	3.10	7.90	6.90	5.80	4.80	3.90	3.10	8.00	7.00	6.00	5.00	4.00	3.20
P_3S_1	8.40	7.50	6.40	5.50	4.40	3.40	8.30	7.30	6.40	5.30	4.40	3.40	8.40	7.40	6.60	5.40	4.50	3.60
P_3S_2	8.30	7.40	6.30	5.40	4.30	3.30	8.20	7.20	6.20	5.20	4.20	3.30	8.30	7.40	6.30	5.40	4.30	3.30
P_3S_3	8.00	7.10	6.00	5.10	4.00	3.00	7.80	6.80	5.70	4.70	3.80	3.00	7.80	6.80	5.70	4.70	3.80	3.00
LSD (P=0.05)	0.206	0.184	0.158	0.135	0.108	0.084	0.203	0.178	0.155	0.129	0.106	0.085	0.204	0.181	0.156	0.131	0.107	0.084

Alcohol content

The initial value of alcohol content of *neera* was found as 2.00 per cent. It was evident from the data that the alcohol content of *neera* increased with the advancement in storage period up to six weeks and ranged from 2.08 to 4.07 per cent.

The maximum increase in alcohol content, *i.e.,* 2.14 to 4.01 and 2.15 to 4.05 per cent, was found from the 1st to 6th week of storage in P_3 and S_3, respectively. The minimum increase in alcohol content, *i.e.,* 2.10 to 3.87 and 2.10 to 3.85 per cent, was recorded from the 1st to 6th week of storage in P_1 and S_1, respectively.

The alcohol content had an increasing trend during the storage period. The degree of fermentation of the palmyrah *neera* depends on the practice of *neera* collection and the environmental condition prevailing in the region (Kurniawan *et al.,* 2020). Hygiene collection of the *neera* samples preserves it in fresh form for comparatively longer durations (Khandekar *et al.,* 2018). An increase in alcohol might be due to the accumulation of organic acids as respiratory substrates in the palmyrah *neera*.

The major physical and chemical changes occurring in the fermenting *neera* indicated that a natural fermentation of palmyrah *neera* consists of an initial lactic acid fermentation, a middle alcoholic fermentation and a final acetic acid fermentation. It also appeared that activities brought about by microorganisms in the early phase helped the activities of the microorganisms in each of the later phases of storage (Atputharajah *et al.,* 1986).

Sensory parameters

The maximum score for taste, flavour and overall acceptability was recorded when *neera* was packed in HDPE 50 micron pouch and stored in cold storage at 2 °C during the entire period of storage (Table 3).

The sensory score for taste, flavour and overall acceptability of *neera* declined from 8.80 to 3.00, 8.90 to 3.00 and 8.70 to 3.00, respectively during storage. On the 1st, 2nd, 3rd, 4th, 5th and 6th week of storage, the highest score for taste, flavour and overall acceptability, *i.e.* 8.80, 7.90, 6.90, 5.90, 4.80, 3.90 and 8.90, 7.80, 6.90, 5.80, 4.80, 3.90 and 8.70, 7.80, 6.80, 5.80, 4.70, 3.80, respectively were recorded in P_1S_1.

The organoleptic score for taste flavour and overall acceptability of *neera* had a decreasing trend during six weeks of storage. The highest organoleptic score for taste, flavour and overall acceptability was recorded for *neera* packed in HDPE 50 micron pouch and stored in cold storage at 2 °C (P_1S_1). It might be due to minimum change in acidity and maximum TSS of *neera* which produce a less organic substance having bad taste. The minimum changes in pH and lower fermentation produce an organic substance having a sour flavour. The highest score of taste and flavour might be the reason for obtaining the highest organoleptic score for overall acceptability. These results are in accordance with (Gobin *et al.,* 2009) in coconut water and (Anonymous, 2013) in palmyra *neera*.

Conclusions

Neera is highly nutritive and a good digestive agent, because of its high fermentable nature it is a major constraint for large scale production and long term storage. The current investigation focused on the use of appropriate packing material and storage conditions to extend the shelf life of palmyrah *neera*. Based on the findings of the present study, it can be concluded that, among different packing material and storage conditions *neera* packed in HDPE 50 micron pouch and stored in cold storage at 2°C found superior for long term storage of palmyrah *neera* and maximum retention of quality and sensory parameters.

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