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RESEARCH ARTICLE

Microwave Treatment of Coconut Inflorescence Sap (Kalparasa®): A Panacea to Preserve Quality Attributes

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Abstract Coconut inflorescence sap, traditionally called as *neera*, is a natural and healthy drink obtained by tapping the unopened immature spadix of coconut. The sap tapped by using the device coco-sap chiller, developed by ICAR-Central Plantation Crops Research Institute, is called Kalparasa®. The shelf life of the sap after extraction is 2–3 h in atmospheric condition. Farmer producer companies and palm sap processing industries require suitable preservation techniques to maintain the physico-chemical properties of the coconut sap. Hence, the effect of microwave power level (600 and 900 W) and exposure time (30, 60, 90, and 120 s) on the physico-chemical properties of Kalparasa stored under refrigerated conditions was investigated. The physico-chemical properties of microwave-treated Kalparasa including pH, TSS, titratable acidity, ascorbic acid, total sugar, reducing sugar, and polyphenols were analysed at 1, 3, 5, 7, 9, 12, and 16 days after storage. The results reveal that the microwave treatment and storage period had a significant effect ($P < 0.001$) on the physico-chemical properties of Kalparasa. Furthermore, it was deduced that a combination of high power (900 W) and exposure time (120 s) maintains the physico-chemical quality of Kalparasa up to 16 days of storage under refrigerated conditions.

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Introduction

Coconut inflorescence sap is a natural and unfermented healthy drink obtained by tapping the unopened immature spadix of the coconut (Borse et al. 2007). In India, it is a traditional health drink consumed largely by the rural population. *Neera* contains sugar that is reported to be good for the human digestive health (Lata and Kamala 1966). Fresh *neera* has a sweet taste and oyster-white colour and maintains a neutral pH (Gupta et al. 1980). Because of high sugar content (12–15%), *neera* is prone to rapid fermentation and it swiftly gets converted into alcohol (5–8%) (Iwuoha and Eke 1996). The fermented *neera* with alcohol content is called toddy.

Thermal treatments are some of the common preservation techniques used to prevent the fermentation of *neera*. However, thermal preservation processes affect the taste, colour, flavour, and nutritional profile of *neera* to great extent. The most common chemical reactions that affect the quality of heated inflorescence sap are caramelization and Maillard reaction (Ho et al. 2007). Researchers from different parts of the world have extensively conducted the thermal pasteurization and/or chemical preservation techniques to improve the shelf life of *neera* (Naknean et al. 2014, 2015; Kapilan et al. 2015; Hebbar et al. 2018). Naknean et al. (2014) reported that chitosan (0.1%) with pasteurization (80 °C for 10 min) has extend the shelf life of *neera* up to 25 days under the storage temperature of 10 °C. Addition of lime (3 g l^{-1}) is effectively inhibiting the fermentation of *neera* (Kapilan et al. 2015). Most of these investigations have concluded that the thermally and/

or chemically treated *neera* differs from the fresh *neera* in terms of nutritional profile and sensory characteristics.

Microwave heating generates volumetric heating within the food material; hence, microwave mode of heating achieves high-quality shelf-stable food products in short treatment time. Also, the original organoleptic quality characteristics of food could be maintained during microwave heating. Unlike the traditional heating methods, microwaves are effective in rapid inactivation of enzymes and microbial contamination (Math et al. 2014) and minimize the loss in quality (Rayman and Baysal 2011).

Kalparasa® is the pure form of *neera* tapped from coconut palm by using coco-sap chiller. Kalparasa significantly differs from *neera* in terms of quality and sensory characteristics. The pH and TSS content of Kalparasa ranges from 6.5–7.5 and 15.5–18 (°Brix), respectively, whereas the conventional *neera* collected by using earthen pot coated with lime has the pH of < 6 and TSS of 13–14 (Hebbar et al. 2018). Colour of the fresh Kalparasa is golden brown and emits no foul odour (Hebbar et al. 2015). Kalparasa contains flavonoids, amino acids, total phenols, and antioxidants which are 4.6, 2.5, 1.5, and 1.8 times, respectively, higher than the traditional *neera* (Hebbar et al. 2018).

Kalparasa could not be stored in atmospheric condition (30 ± 2 °C) as it undergoes rapid fermentation in 2–3 h. Suitable processing techniques are imperative to slow down the process of fermentation in order to increase the shelf life of the Kalparasa. Unfermented Kalparasa is an invaluable raw material for the production of various non-alcoholic beverages, sugar, and jaggery, and value added products including ice cream, chocolate, jelly, sweets, cake, and jam (Hebbar et al. 2015). Hence, the objective of this present work is to study the effects of microwave power level and exposure time on the quality and shelf life of Kalparasa under refrigerated (4–6 °C) storage condition.

Materials and Methods

Kalparasa Collection

Coconut palms cultivated in the research farm of ICAR-Central Plantation Crops Research Institute (CPCRI), Kasaragod, India, were tapped to extract Kalparasa. The fresh, hygienic, and unfermented sap was collected by using the in-house developed portable icebox device coco-sap chiller (Fig. 1a) (Hebbar et al. 2015). This insulated device maintains the temperature of 2–3 °C around the Kalparasa collection container for 10–12 h (Hebbar et al. 2015). The low temperature conditions reduce the activity of microbes and yeasts, thus helps to maintain the quality of Kalparasa during the process of tapping.

Sample Preparation

Kalparasa (Fig. 1b) collected using coco-sap chiller was immediately brought to the laboratory in an icebox and filled in pre-sterilized microwavable polypropylene bottle (Tarsons Narrow Mouth Bottle: 125 ml capacity) under aseptic conditions. Each bottle maintained in icebox was filled with 75 ml of sap and capped immediately. All these activities were carried out inside the laminar airflow chamber to avoid the contamination during filling and handling.

Microwave Pasteurization

Domestic microwave oven (Samsung, Model no., CE1041DFB1 and 2450 MHz frequency) was used in the experiment. The samples were treated at two microwave power levels (600 and 900 W) and four exposure times (30, 60, 90, and 120 s). All the treatments were carried out thrice. The sample which was not treated in a microwave oven served as a control. The bottles filled with Kalparasa were placed in the centre of the microwave oven chamber at mouth opened condition along with cap to avoid the development of pressure inside the bottle and to avoid the bursting of bottles at high exposure time. The power level and exposure time were adjusted using the digital controlled system. Maximum temperature attained in the sap (at the end of each treatment) was measured using an IR thermometer. The capping of bottles was done immediately after the microwave treatment. Capped bottles were wrapped with cling film to ensure the airtight sealing. The treated samples were kept under refrigerated condition (4–6 °C) for shelf life studies.

Physico-Chemical Parameters

The pH and TSS were measured using a digital pH meter (PcTestr35, Eutech instruments) and ATAGO digital refractometer. Total titratable acidity as citric acid was estimated by a titrimetric method against the alkali solution (0.01 N sodium hydroxide) and using phenolphthalein as an indicator (Ranganna 1986). Similarly, the ascorbic acid content of Kalparasa was also determined by the titrimetric method. The concentration of total soluble sugars was estimated by phenol sulphuric acid method (Dubois et al. 1956). Reducing sugar content of Kalparasa was estimated by following the method of Nelson and Somogyi (Somogyi 1952). Total phenols were estimated by using the Folin Ciocalteus (FC) method (Bray and Thorpe 1954).

Fig. 1 Coco-sap chiller (**a**) used to collect Kalparasa (**b**) from coconut palm

Statistical Analysis

The individual (power level, exposure time, and storage days) and combined effect of treatment on physico-chemical properties of Kalparasa was analysed by factorial CRD design. The significance of the treatments was compared at the probability level of $P < 0.001$(***), $P < 0.01$(**), and $P < 0.05$(*).

Results and Discussion

Temperature Profile of the Microwave Pasteurized Samples

Temperature differences of the sap before and after treatment provided the total increment in temperature of the fresh Kalparasa sample. Temperature of the sap (before and after treatment) was measured by using IR thermometer. The base temperature of the Kalparasa was 10 ± 1 °C. Temperature of the treated sample increased as the exposure time increased from 30 to 120 s. The lowest temperature of 35 °C was recorded in the treatment combination of 600 W for 30 s, whereas the highest temperature of 99 °C was documented when the Kalparasa was subjected to the microwave treatment of 900 W for 120 s.

Variation in pH at Different Microwave Treatments

Quality of Kalparasa could be easily evaluated based on the pH values of the sap. The changes in the pH of Kalparasa during refrigerated storage condition are presented in Table 1. The pH of fresh Kalparasa was found to be 6.6. It was observed that the microwave heating significantly ($P < 0.001$) increased the pH of Kalparasa and the increase in pH was directly proportional to power level and exposure time. The statistical analysis indicated that the power level of 900 W for 90 s exposure and 600 W for 120 s exposure was on par with each other, followed by 600 W for 90 s treatment and 900 W for 60 treatment with mean pH of 6.8 and 6.7, respectively. The maximum and minimum pH values of 8.4 and 6.6 were observed in treatment combination of 900 W for 120 s and 600 W for 30 s, respectively. The increase in pH value could be due to the reduction in organic acids content of the sap during heating. Similar spike in the pH of pasteurized palm sap (*Borassus flabellifer* L.) was documented by Naknean et al. (2014). Pierre et al. (2009) found that pH of apple puree had a slight increase from 3.2 to 3.3 after microwave heating at 652 W for 35 s. Nevertheless, we have observed that the treatment of Kalparasa for 600 W for 30 s did not increase the pH due to low heat generated (35 °C) during microwave treatment, which was not sufficient to evaporate organic acids.

Irrespective of the microwave power level and exposure time, the pH of Kalparasa exhibited a decreasing trend with storage time. The pH of Kalparasa reduced significantly ($P < 0.001$) after 16 days of storage (Table 7). It might be attributed to the lactic acid production during natural fermentation. The decline in pH could probably be due to the accumulation of the acidic compounds by the activity of micro-organisms present in palm juice (Judoamidjojo et al. 1989). The rate of decline was high in control compared to microwave-treated samples. Among the treatments, 600 W–90 s, 600 W–120 s, 900 W–60 s, 900 W–90 s, and 900 W–120 s have maintained the pH of 6.6–8.3 up to 16 days of storage. Thus, the rate of microbial destruction was directly proportional to the heating temperature. The

Table 1 Effect of microwave pasteurization on pH of Kalparasa stored under refrigerated condition

Power level	Exposure time								Storage days
	0	1	3	5	7	9	12	16	Mean
Control	6.6 ± 0.1	5.1 ± 0.1	4.5 ± 0.0	4.3 ± 0.2	4.2 ± 0.1	4.0 ± 0.1	3.9 ± 0.2	3.8 ± 0.0	4.5
600 W									
30 s	6.6 ± 0.1	5.0 ± 0.1	4.6 ± 0.1	4.2 ± 0.1	3.9 ± 0.0	3.6 ± 0.0	3.6 ± 0.1	3.5 ± 0.1	4.3
60 s	6.8 ± 0.0	6.5 ± 0.2	6.5 ± 0.2	6.6 ± 0.2	6.5 ± 0.2	6.6 ± 0.1	6.5 ± 0.1	6.1 ± 0.2	6.5
90 s	7.0 ± 0.0	6.9 ± 0.1	6.8 ± 0.1	6.7 ± 0.2	6.7 ± 0.1	6.7 ± 0.2	6.8 ± 0.1	6.7 ± 0.1	6.8
120 s	7.3 ± 0.1	7.1 ± 0.0	7.2 ± 0.2	7.2 ± 0.1	7.1 ± 0.1	7.2 ± 0.3	7.1 ± 0.2	7.1 ± 0.0	7.2
900 W									
30 s	6.7 ± 0.1	6.0 ± 0.2	4.3 ± 0.2	4.1 ± 0.0	4.1 ± 0.1	3.9 ± 0.2	3.9 ± 0.3	3.7 ± 0.2	4.5
60 s	7.2 ± 0.0	6.9 ± 0.1	6.6 ± 0.1	6.7 ± 0.1	6.7 ± 0.2	6.6 ± 0.1	6.6 ± 0.1	6.6 ± 0.2	6.7
90 s	7.6 ± 0.2	7.5 ± 0.1	7.4 ± 0.1	7.4 ± 0.1	7.4 ± 0.2	7.3 ± 0.2	7.1 ± 0.1	7.1 ± 0.1	7.4
120 s	8.4 ± 0.1	8.4 ± 0.3	8.2 ± 0.2	8.2 ± 0.2	8.1 ± 0.2	8.2 ± 0.2	8.3 ± 0.1	8.3 ± 0.1	8.3
Mean	7.1	6.6	6.2	6.1	6.1	6.0	6.0	5.9	6.3

high temperatures generated at relatively high exposure times may kill major micro-organisms present in Kalparasa, thus maintains the quality for longer storage period.

Variation in Total Soluble Solids (TSS) at Different Microwave Treatments

One of the major nutrient sources for micro-organisms to cause fermentation is sugars that form an important component of total soluble solids. Hence, TSS content effectively determines the probability and the rate of fermentation. The data on effect of microwave pasteurization treatments on TSS of Kalparasa stored under refrigerated storage condition are presented in Table 2. TSS content of the Kalparasa was found to be significant ($P < 0.001$) increase after the microwave treatment (Table 7). Table 2 depicts that the TSS of Kalparasa increases from 16.8°Brix (in control) to 18.9°Brix (900 W–120 s) after the treatment. This may be due to changes in the vibrational density, chemical composition, and structure of water (Yakunov et al. 2017) molecules present in Kalparasa. Also, the surface evaporation of water present in Kalparasa could be directly related to temperature rise during microwave treatment. This might cause an increase in TSS. It was not uncommon to observe the loss of

Table 2 Effect of microwave pasteurization on total soluble solid (°Brix) of Kalparasa stored at refrigerated condition

Power level	Exposure time								Storage days
	0	1	3	5	7	9	12	16	Mean
Control	16.8 ± 0.0	14.4 ± 0.2	13.7 ± 0.0	13.5 ± 0.0	13.2 ± 0.1	12.6 ± 0.0	12.7 ± 0.2	12.4 ± 0.4	13.7
600 W									
30 s	16.8 ± 0.0	15.0 ± 0.1	14.9 ± 0.1	14.5 ± 0.0	14.2 ± 0.0	13.8 ± 0.2	13.7 ± 0.0	12.6 ± 0.1	14.4
60 s	16.9 ± 0.1	15.2 ± 0.0	15.1 ± 0.0	15.3 ± 0.1	15.3 ± 0.1	15.3 ± 0.1	15.6 ± 0.2	15.4 ± 0.1	15.5
90 s	17.0 ± 0.0	15.1 ± 0.0	15.3 ± 0.0	15.1 ± 0.0	15.2 ± 0.0	15.3 ± 0.2	15.2 ± 0.1	14.7 ± 0.2	15.3
120 s	17.2 ± 0.0	15.4 ± 0.1	14.8 ± 0.0	15.5 ± 0.2	16.1 ± 0.2	16.0 ± 0.4	16.2 ± 0.4	15.6 ± 0.1	15.8
900 W									
30 s	17.0 ± 0.1	15.2 ± 0.0	14.8 ± 0.0	14.6 ± 0.0	14.4 ± 0.0	13.9 ± 0.1	13.7 ± 0.1	13.2 ± 0.0	14.6
60 s	17.4 ± 0.0	15.3 ± 0.0	15.2 ± 0.2	15.1 ± 0.0	15.3 ± 0.0	15.2 ± 0.0	15.2 ± 0.2	14.7 ± 0.2	15.3
90 s	17.8 ± 0.0	15.5 ± 0.2	15.3 ± 0.1	15.7 ± 0.1	16.3 ± 0.1	15.8 ± 0.2	16.4 ± 0.1	16.2 ± 0.1	16.1
120 s	18.9 ± 0.0	17.2 ± 0.4	16.7 ± 0.0	16.5 ± 0.2	16.4 ± 0.1	16.2 ± 0.1	16.6 ± 0.4	16.4 ± 0.3	16.8
Mean	17.3	15.3	15.1	15.0	15.1	14.9	15.0	14.5	15.3

Table 3 Effect of microwave pasteurization on titratable acidity (%) of Kalparasa stored at refrigerated condition

Power level	Exposure time								Storage days
	0	1	3	5	7	9	12	16	Mean
Control	0.03 ± 0.00	0.25 ± 0.04	0.28 ± 0.08	0.31 ± 0.01	0.32 ± 0.10	0.35 ± 0.02	0.41 ± 0.08	0.43 ± 0.02	0.30
600 W									
30 s	0.03 ± 0.01	0.20 ± 0.06	0.22 ± 0.06	0.23 ± 0.06	0.31 ± 0.08	0.32 ± 0.02	0.35 ± 0.02	0.42 ± 0.02	0.26
60 s	0.02 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.04 ± 0.00	0.04 ± 0.01	0.07 ± 0.01	0.10 ± 0.00	0.15 ± 0.03	0.06
90 s	0.02 ± 0.00	0.03 ± 0.01	0.02 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.06 ± 0.01	0.03
120 s	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.03 ± 0.00	0.02
900 W									
30 s	0.03 ± 0.01	0.04 ± 0.01	0.20 ± 0.02	0.22 ± 0.06	0.23 ± 0.06	0.32 ± 0.02	0.35 ± 0.04	0.49 ± 0.02	0.24
60 s	0.02 ± 0.00	0.02 ± 0.00	0.03 ± 0.00	0.02 ± 0.00	0.04 ± 0.01	0.03 ± 0.00	0.03 ± 0.00	0.04 ± 0.00	0.03
90 s	0.01 ± 0.00	0.03 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.03 ± 0.00	0.02
120 s	0.01 ± 0.00	0.01 ± 0.00	0.03 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.01 ± 0.00	0.02 ± 0.00	0.03 ± 0.00	0.03
Mean	0.02	0.07	0.10	0.10	0.11	0.15	0.14	0.17	0.11

Table 4 Effect of microwave pasteurization on ascorbic acid (mg/100 ml) content of Kalparasa stored at refrigerated condition

Power level	Exposure time								Storage days
	0	1	3	5	7	9	12	16	Mean
Control	16.5 ± 0.1	16.4 ± 1.1	16.2 ± 0.8	15.9 ± 1.0	16.2 ± 0.2	13.5 ± 0.8	12.4 ± 0.4	11.8 ± 0.4	15.1
600 W									
30 s	16.4 ± 0.2	14.1 ± 0.2	15.2 ± 0.4	15.0 ± 0.2	13.8 ± 0.6	13.1 ± 0.2	12.8 ± 0.2	12.2 ± 0.1	14.7
60 s	16.2 ± 0.2	16.4 ± 0.8	16.5 ± 0.4	16.2 ± 0.6	15.9 ± 0.4	14.9 ± 0.1	14.6 ± 0.1	14.0 ± 0.2	15.6
90 s	16.4 ± 0.1	16.6 ± 0.2	16.2 ± 0.1	16.6 ± 0.4	15.0 ± 0.4	14.9 ± 0.1	14.4 ± 0.1	13.8 ± 0.2	15.4
120 s	16.0 ± 0.0	16.0 ± 0.2	16.1 ± 0.1	15.7 ± 0.4	15.7 ± 0.8	15.2 ± 0.6	14.5 ± 0.2	13.4 ± 0.4	15.3
900 W									
30 s	16.4 ± 0.2	16.3 ± 0.2	15.8 ± 0.1	16.9 ± 0.1	16.8 ± 0.2	15.0 ± 0.2	14.1 ± 0.2	12.7 ± 0.2	15.4
60 s	16.1 ± 0.1	15.5 ± 0.1	15.9 ± 0.0	16.1 ± 0.0	15.9 ± 0.1	15.0 ± 0.4	13.6 ± 0.1	12.5 ± 0.1	15.1
90 s	15.9 ± 0.1	15.3 ± 0.0	15.5 ± 0.1	15.3 ± 0.0	15.1 ± 0.1	15.0 ± 0.4	12.6 ± 0.4	13.4 ± 0.0	14.7
120 s	15.5 ± 0.0	15.4 ± 0.0	15.3 ± 0.0	15.5 ± 0.1	15.6 ± 0.1	15.5 ± 0.1	15.2 ± 0.2	13.7 ± 0.1	15.2
Mean	16.1	15.7	16.0	16.0	15.5	14.7	13.8	13.0	15.1

moisture following microwave treatment of juices such as pomelo at 90 °C (Kumar et al. 2017).

Table 2 shows gradual decrease in TSS content of Kalparasa during storage period. With the increase in the storage days, solid content of the Kalparasa declined to great extent due to its deterioration or utilization of nutrients by micro-organisms. Among the treatments, 900 W for 120 s was found to be efficient to maintain the maximum TSS content on 16 days after storage (DAS), whereas the control sample maintained minimum TSS content of 16.8, 14.4, 13.7, 13.5, 13.2, 12.6, 12.7, and 12.4°Brix at 0, 1, 3, 5, 7, 9, 12, and 16 DAS, respectively. This might be attributed to the conversion of sap into alcohol and subsequent transformation into vinegar by the activity of natural yeast and acetic acid bacteria. Similarly, Legaz et al. (2000) reported that the yeast could destroy the soluble solids especially conversion of sugars into ethanol; thus, the sugar content declined.

Variation in Titratable Acidity at Different Microwave Treatments

The data on effect of microwave pasteurization treatments on titratable acidity of Kalparasa under refrigerated storage condition are presented in Table 3. Microwave treatment significantly ($P < 0.001$) influences the acidity value

Table 5 Effect of microwave pasteurization on total sugar (%) content of Kalparasa stored at refrigerated condition

Power level	Exposure time								Storage days
	0	1	3	5	7	9	12	16	Mean
Control	15.1 ± 0.0	12.3 ± 0.9	11.9 ± 1.1	10.2 ± 0.5	10.1 ± 0.4	9.6 ± 0.2	6.6 ± 0.2	6.0 ± 0.6	10.2
600 W									
30 s	15.1 ± 0.1	12.1 ± 0.3	11.9 ± 0.1	11.7 ± 0.3	10.1 ± 0.1	9.5 ± 0.9	6.6 ± 0.6	5.8 ± 0.4	10.3
60 s	15.2 ± 0.0	14.1 ± 0.1	13.8 ± 0.2	13.6 ± 0.2	13.3 ± 0.2	12.8 ± 1.2	12.1 ± 0.1	11.5 ± 0.2	13.3
90 s	15.4 ± 0.2	15.2 ± 0.1	14.8 ± 0.2	14.8 ± 0.4	14.6 ± 0.4	14.5 ± 0.8	14.5 ± 0.4	14.2 ± 0.2	14.7
120 s	15.5 ± 0.2	15.3 ± 0.3	15.2 ± 0.1	15.0 ± 0.4	14.9 ± 0.6	14.7 ± 0.3	14.5 ± 0.2	14.4 ± 0.1	14.9
900 W									
30 s	15.2 ± 0.0	12.5 ± 0.1	12.1 ± 0.1	11.3 ± 0.2	10.4 ± 0.1	8.3 ± 1.2	8.0 ± 0.1	6.8 ± 0.8	10.6
60 s	15.4 ± 0.1	15.0 ± 0.2	15.0 ± 0.4	14.6 ± 0.1	14.4 ± 0.0	14.2 ± 0.2	14.4 ± 0.1	14.2 ± 0.1	14.6
90 s	15.5 ± 0.0	15.4 ± 0.2	15.2 ± 0.1	15.2 ± 0.2	15.1 ± 0.2	14.7 ± 0.1	14.5 ± 0.1	14.2 ± 0.0	15.0
120 s	15.6 ± 0.0	15.3 ± 0.1	15.2 ± 0.2	15.1 ± 0.1	14.9 ± 0.0	14.7 ± 0.1	14.6 ± 0.1	14.4 ± 0.1	15.0
Mean	15.3	14.1	13.9	13.5	13.1	12.5	11.7	11.3	13.2

(Table 7). Kumar et al. (2017) reported the increase in titratable acidity of microwave-treated pomelo juice probably due to oxidation of reducing sugars. Atputharajah et al. (1986) found that the micro-organisms in Kalparasa constitute initial lactic acid fermentation, a middle alcoholic fermentation, and a final acetic fermentation during the natural fermentation process. Hence, the titratable acidity of the Kalparasa increased with increase in storage period (Table 3). The data on per cent titratable acidity during storage indicate the significant ($P < 0.001$) differences among the treatments (Table 7). The maximum titratable acidity was found in control sample with the values of 0.03, 0.25, 0.28, 0.31, 0.32, 0.35, 0.41, and 0.43% at 0, 1, 3, 5, 7, 9, 12, and 16th DAS, respectively. The next high level of titratable acidity was found in 600 W for 30 s and 900 W for 30 s with the mean values of 0.26% and 0.24% which were on par with each other. This indicates that more acids are produced during lactic acid fermentation which was favoured by ideal growing conditions for microbes. However, all the other microwave treatments maintained the titratable acidity. This could be due to high exposure time (> 30 s) that could have killed the fermenting micro-organisms.

Variation in Ascorbic Acid at Different Microwave Treatments

Ascorbic acid (mg/100 ml) content of Kalparasa stored under refrigerated conditions as influenced by microwave pasteurization is presented in Table 4. A slight decrease in the ascorbic acid content of Kalparasa after microwave heating (0th day of storage) was observed. This could be attributed to the inherent degrading and easily oxidizable nature of ascorbic acid while heating. The mean ascorbic acid content was recorded as 16.1 mg per 100 ml on the initial day of storage. Among the microwave power level, non-significant changes were noticed (Table 7). However, the maximum mean value of 15.6 mg per 100 ml of ascorbic acid content was observed in treatment of 600 W for 60 s, whereas the minimum values of ascorbic acid were observed in treatment of 900 W for 90 s with the mean value of 14.7 mg per 100 ml was observed. Table 4 shows that the ascorbic acid content of Kalparasa ultimately declines at the end of storage irrespective of the treatments. The mean values of ascorbic acid at 1, 3, 5, 7, 9, 12, and 16th DAS were 15.7, 16.0, 16.0, 15.5, 14.7, 13.8, and 13.0 mg/100 ml, respectively, showed a decrease in first day and increased on 3rd and 5th day and then decreasing trend up to 16th DAS. This increasing trend could be due to the activity of yeast which synthesizes vitamin C during fermentation (Bremus et al. 2006).

Variation in Total Sugar at Different Microwave Treatments

The main sugar constituents of the palm sap are sucrose, glucose, and fructose and among which sucrose predominates (Naknean et al. 2010). The data on the effect of microwave pasteurization on the total sugar content of Kalparasa kept under refrigerated storage condition are presented in Table 5. Total sugar content of treated samples was found to increase after treatment similar to the content of total soluble solids due to moisture loss. Naknean et al. (2015) observed a positive correlation between the total sugar and TSS, suggesting that the highest proportion of the soluble solid in pasteurized palm sap was sugars.

Table 6 Effect of microwave pasteurization on reducing sugar (%) content of Kalparasa stored at refrigerated condition

Power level	Exposure time								Storage days
	0	1	3	5	7	9	12	16	Mean
Control	0.5 ± 0.0	3.1 ± 0.3	3.4 ± 0.4	5.1 ± 0.8	5.4 ± 0.6	2.9 ± 0.2	2.4 ± 0.2	1.1 ± 0.1	3.0
600 W									
30 s	0.6 ± 0.1	3.2 ± 0.1	3.4 ± 0.1	3.6 ± 0.1	5.3 ± 0.1	5.0 ± 0.4	2.1 ± 0.1	1.0 ± 0.0	3.0
60 s	0.5 ± 0.0	1.3 ± 0.4	1.6 ± 0.2	1.9 ± 0.1	2.2 ± 0.2	2.7 ± 0.3	3.4 ± 0.3	2.8 ± 0.1	2.0
90 s	0.5 ± 0.0	0.7 ± 0.0	1.0 ± 0.1	1.1 ± 0.0	1.1 ± 0.1	0.9 ± 0.0	1.3 ± 0.0	1.4 ± 0.2	1.0
120 s	0.5 ± 0.0	0.9 ± 0.0	1.1 ± 0.1	1.1 ± 0.0	1.2 ± 0.1	1.0 ± 0.1	1.2 ± 0.0	1.1 ± 0.0	1.0
900 W									
30 s	0.5 ± 0.0	1.8 ± 0.4	2.3 ± 0.6	2.9 ± 0.3	3.9 ± 0.1	5.0 ± 0.4	3.2 ± 0.1	2.1 ± 0.2	2.7
60 s	0.5 ± 0.0	0.7 ± 0.2	0.8 ± 0.0	1.1 ± 0.1	0.6 ± 0.0	1.0 ± 0.0	1.3 ± 0.0	0.9 ± 0.1	0.8
90 s	0.5 ± 0.0	0.8 ± 0.0	0.8 ± 0.0	0.6 ± 0.0	0.6 ± 0.0	0.9 ± 0.0	1.2 ± 0.1	0.9 ± 0.1	0.8
120 s	0.6 ± 0.0	0.9 ± 0.1	1.0 ± 0.1	0.9 ± 0.0	0.6 ± 0.0	1.1 ± 0.1	1.2 ± 0.0	1.1 ± 0.0	0.9
Mean	0.5	1.5	1.7	2.0	2.3	2.3	1.9	1.4	1.7

Table 7 ANOVA for physico-chemical characteristics of Kalparasa

Parameters	*df*	pH	TSS	Titratable acidity	Ascorbic acid	Total sugar	Reducing sugar	Total phenol
Power level (*P*)	1	566.22***	462.76 ***	28.76***	0.22 NS	82.41***	367.59***	9.11**
Exposure time (*T*)	3	4121.23***	1265.21 ***	1205.59***	37.00***	1749.28***	1527.46***	1540.03***
Storage days (*D*)	7	131.26***	645.04 ***	88.58***	339.94***	244.64***	237.26***	937.28***
P * *T*	3	92.30***	141.52 ***	4.40**	147.86***	35.18***	115.71***	33.79***
T * *D*	21	60.54***	44.64 ***	48.79***	11.39***	70.38***	116.50***	88.00***
P * *D*	7	5.48***	10.38***	2.36*	14.32***	5.11***	19.88***	112.39 ***
P * *T* * *D*	21	3.11***	16.93 ***	6.15***	8.91***	3.61***	25.89***	16.42***

NS non-significant

***Significant at 0.001; **significant at 0.01; *significant at 0.05

On the day of storage, the mean value of total sugar content was 15.3%. The mean values of total sugar content were 14.1, 13.9, 13.5, 13.1, 12.5, 11.7, and 11.3% at 1, 3, 5, 7, 9, 12, and 16 DAS, respectively, indicating the decline in the sugar content with the increase in storage period. High exposure time (> 60 s) at the power levels of 600 W and 900 W maintained maximum mean total sugar content, whereas low exposure time (30 s) in both the power levels recorded sugar content similar to that of the control. Result of the treatment 600 W for 30 s was on par with control. However, the maximum total sugar content was observed in 900 W for 120 s and 900 W for 90 s with the mean value of 15%; both treatments were on par with each other. It indicates that a threshold temperature must be achieved to kill the organisms and to decrease the activity of enzymes involved in hydrolysis of sucrose. Juan et al. (2001) reported that higher microbial reductions were observed at higher power and longer processing time with the temperatures of 70–76 °C.

Variation in Reducing Sugar at Different Microwave Treatments

The data pertaining to reducing sugar content of Kalparasa as influenced by microwave pasteurization are presented in Table 6. On the initial day of storage, the mean reducing sugar content was 0.5%. Microwave treatment significantly ($P < 0.001$) influences the reducing sugar content (Table 7). Significant increase in reducing sugar content was noticed after microwave pasteurization; it might be due to the conversion of non-reducing sugars into reducing sugars as observed by Mehmood et al. (2008) with apple juice.

Reducing sugar content of the fresh sample was less (0.5%), as increase in the storage days increased the

Table 8 Effect of microwave pasteurization on total phenol content (mg/100 ml) of Kalparasa stored at refrigerated condition

Power level	Exposure time								Storage days
	0	1	3	5	7	9	12	16	Mean
Control	18.3 ± 0.1	22.2 ± 0.7	22.9 ± 0.3	23.3 ± 0.4	23.9 ± 0.6	24.1 ± 0.6	25.2 ± 1.2	27.6 ± 0.9	23.5
600 W									
30 s	18.2 ± 0.2	21.1 ± 0.2	22.1 ± 0.0	23.7 ± 0.8	23.4 ± 0.2	24.9 ± 0.3	25.9 ± 0.4	23.7 ± 1.3	22.9
60 s	17.8 ± 0.1	20.5 ± 0.1	21.3 ± 0.1	22.8 ± 0.2	22.8 ± 0.4	23.7 ± 0.5	22.0 ± 0.2	17.8 ± 0.1	21.1
90 s	16.6 ± 0.0	19.6 ± 0.4	20.2 ± 0.1	21.4 ± 0.1	21.5 ± 0.1	22.9 ± 0.1	22.2 ± 0.1	16.6 ± 0.2	20.1
120 s	16.5 ± 0.0	18.2 ± 0.3	19.2 ± 0.0	20.1 ± 0.0	21.6 ± 0.1	20.9 ± 0.1	18.6 ± 0.0	16.5 ± 0.1	19.0
900 W									
30 s	18.3 ± 0.1	22.9 ± 0.1	23.2 ± 1.2	23.8 ± 0.2	24.1 ± 0.4	25.1 ± 0.4	25.6 ± 0.1	22.5 ± 0.7	23.2
60 s	17.5 ± 0.0	21.4 ± 0.2	22.7 ± 0.2	23.9 ± 0.5	23.9 ± 0.1	24.4 ± 0.2	20.6 ± 0.4	17.1 ± 0.3	21.4
90 s	17.5 ± 0.0	20.5 ± 0.1	21.2 ± 0.0	22.4 ± 0.0	22.9 ± 0.3	19.1 ± 0.0	16.9 ± 0.2	14.5 ± 0.2	19.4
120 s	16.4 ± 0.0	19.9 ± 0.0	20.2 ± 0.1	20.6 ± 0.0	21.5 ± 0.1	20.1 ± 0.0	14.9 ± 0.2	14.1 ± 0.6	18.8
Mean	17.5	20.8	21.4	22.4	22.7	22.8	21.3	18.9	21.0

reducing sugar content due the spike in glucose and fructose content of the sap. The results indicated that the mean value of reducing sugar content with respect to storage days exhibited an increasing trend up to 9 DAS (1.5, 1.7, 2.0, 2.3, and 2.3%) and declined thereafter, i.e. on 12th and 16th DAS, it was declining to 1.9 and 1.4%, respectively. This indicates the complete fermentation took place where acetic acid bacteria have utilized the reducing sugar available in the sap, which were produced during third phase of fermentation (Xia et al. 2011). Premalatha et al. (2017) also reported similar trend for reducing sugar under natural fermentation of sap.

Variation in Total Phenols at Different Microwave Treatments

Phenols are important class of biomolecules that function as antioxidant agents thereby protecting the cellular molecules from free radical-induced damage. The data pertaining to total phenol content of Kalparasa as influenced by microwave pasteurization treatments during refrigerated storage conditions are presented in Table 8. On the initial day of storage, the mean total phenol content was 17.5 mg per 100 ml. The results indicated that the mean values of total phenols exhibited an increasing trend up to 9 DAS (20.8, 21.5, 22.4, 22.7, and 22.8 mg/100 ml) and decline thereafter, i.e. on 12 and 16th days, it was 21.3 and 18.9 mg per 100 ml, respectively. Zhang and Wen (2013) and Zhang et al. (2010) found that microwave treatment increased the total polyphenol content in peach and apple juice by the reducing activity of enzymes such as *polyphenol oxidases*.

The maximum mean total phenol content of 23.5 mg per 100 ml was observed in control with the increasing trend of 18.3, 22.2, 22.9, 23.3, 23.9, 24.1, 25.2, and 27.6 mg per 100 ml on 0, 1, 3, 5, 7, 9, 12, and 16 DAS, respectively. The similar trend with the next higher mean total phenol content of 22.9 mg per 100 ml was recorded in 600 W for 30 s. However, the lowest mean total phenol content of 18.8 mg per 100 ml was maintained by 900 W for 120 s with an increasing trend of 16.4, 19.9, 20.2, 20.6, and 21.5 mg per 100 ml on 0, 1, 3, 5, and 7 DAS, respectively, and the decreasing trend of 20.1, 14.9, and 14.1 mg per 100 ml on 9, 12, and 16 DAS, respectively. Pierre et al. (2009) also found decline in phenol content at 5, 8, and 14 DAS in microwave-treated apple puree stored less than 5 °C condition.

Conclusions

Microwave heating precludes the disadvantages associated with slow-thermal diffusion process-based conventional heating. The results confirmed that the microwave heating significantly reduced the total heating time and minimize the undesirable changes in Kalparasa during storage. The high power level (900 W) and higher exposure time (120 s) maintain the quality of Kalparasa up to 16 DAS under refrigerated condition. Kalparasa contains heat labile components such as ascorbic acid; thus, high-temperature and short-time treatment retains the biochemical properties of Kalparasa. Development of continuous-type microwave pasteurization unit to treat the bottled Kalparasa could be the future line of work.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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