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Effect of microwave heating on physico-chemical characteristics of coconut water

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Abstract
Coconut water (*Cococus Nucifera.* L) is the clear liquid present inside a coconut liquid endosperm. This water is subjected to microbial contamination and degrades while exposed to ambient air. In general, thermal methods are mostly used in the preservation of liquid foods. In this study, the coconut water was collected from 8-10 months old harvested coconut. Microwave power levels of 540 W, 720 W, and 900 Whavebeen used to treat the coconut water with different exposure times. The treated coconut water was filled in PET bottles and stored at cool temperature (4 °C) and room temperature (27 °C). It is observed that microwave treated 540 W, 720 W, and 900 W coconut water has maintained the quality during the storage period. The physico-chemical properties of microwave-treated coconut water includecolor, pH, TSS, acidity, and reducing sugar on 15days of storage was measured as 13.18 to 15;5.4 to 4.8; 4.5 to 6.0;0.07 to 0.30; and 1.8 to 3.3% respectively.

Keywords: Coconut water, physicochemical properties, and microwave heating

1. Introduction
Coconut (*Cocos Nucifera.* L) is an essential tropical fruit that can be turned into various foods and beverages. According to the Ministry of Agriculture and Farmer Welfare (2018-2019) report, India's total coconut area was around 2,178.74 thousand hectares under coconut cultivation 21,84.33 million developed nuts, and nut productivity per ha. Was 9,815. Among India's states, Kerala occupied first place in terms of cultivation area (756.89 ha), whereas Karnataka state occupied the second-highest (615.28 Ha) in 2018-19(Department of Agriculture Cooperation and Farmer Welfare, 2019). Coconut is widely utilized as a food product in tropical countries since it contains essential micronutrients that are important to human fitness (DebMandal and Mandal, 2011) [6]. Coconut constitutes two edible parts in the nut's inner portion a kernel and a clear liquid. These parts are processed in many different by-products such as virgin coconut oil, kernel, cake, neera, teddy, wood-based products, leaves, copra, cream, milk, desiccated coconut, etc. (Phadke *et al.*, 2010) [13]. Coconut water is a popular refreshing sweet drink distinctive from coconut milk. Coconut water is a transparent liquid considered a highly nutritive liquidand widely used for rehydration after physical activity (Saat *et al.*, 2002) [20]. Coconut water contains natural electrolytes such as potassium, sodium, and manganese (Deb Mandal and Mandal, 2011) [6]. These properties are used in making a valuable agricultural food commodity. Significantly, the recent findings revealed a novel medicinal property in coconut water that representsthe excellent potential for human health recovery (Yong *et al.*, 2009) [27].

Coconut water contains the nutrients required for maintaining good health but it can't be stored for a long time (Li and Dharmasena, 2016) [10]. Preservation needs to get rid of pleasant smell or color changes. Thermal processing is one of the techniques used in the food industry to preserve the product and improve the shelf life. Thermal heating inactivates spoilage and pathogenic microorganisms during processing. Among different thermal treatment methods, microwave heating has advantages in processing and quality maintenance. The destruction in the electric- field of the fast-changing polarity of weak hydrogens resulting from the dipole rotation of free water like molecules and the electric movement of dissolved ions induces microwave heating. (Prades *et al.*, 2012) [15].

There were less maintenance and low energy consumption in thermal treatment. Hence, the present experiment aimed to research the effect of microwave thermal treatment on coconut water's physicochemical properties.

2. Materials and Methods

2.1 Coconut water collection

Fresh coconut is procured from the local shop, Thanjavur, Tamil Nadu. After cleaning the husk, coconut water was manually extracted by breaking the coconut using a special knife. For each experiment, water from fifteen coconuts was poured and mixed in a 2 liters glass beaker kept in an icebox and stored in refrigerated condition. Three samples (approximately 150ml each) were taken for each microwave power level experiment and exposure time. The treated samples were packed in PET containers and analyzed for total soluble solids, pH, titratable acidity, color (L*, a* and b*), turbidity, and electrical conductivity during storage.

2.2 Microwave treatment

A lab microwave oven (LG, Model No., MC2844EB, and 2450 MHz frequency) has used in this experiment (Figure 1). The sample was treated at three power levels (540, 720, and 900 W) and one exposure time (120 s) respectively. All three treatments triplicates have been performed. The untreated coconut water sample served as a control. 100ml of coconut water filled a glass flask and placed in the centre of the microwave oven. The power level and exposure time were adjusted using the PLC digital system. The sample temperature was measured with an IR thermometer after treatment. Treated samples were cooled immediately in cool conditions at 4°C. These treated samples were filled in the PET bottles and stored at refrigerated conditions for shelf-life studies.

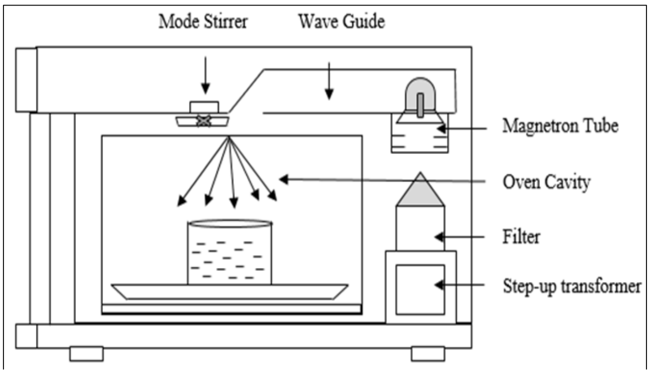

Fig 1: microwave heating for coconut water

2.3 Analytical method

2.3.1 pH

The coconut water pH was determined with a 720 Digital pH meter (INFRA DIGI -digital microcontroller pH meter, Infra Instruments Private Limited). The pH meter was calibrated using a pH buffer of 4.0, 7.0, and 10. The pH meter probe was inserted in coconut water, and the stable readings were recorded as the pH (Sanganamoni *et al*., 2017) [19].

2.3.2 Acidity

The acidity of coconut water was determined using phenolphthalein as an indicator by titrating 10 mL of the sample taken with neutralized alcohol with 0.1 N (NaOH). The total acidity percentage has been expressed as the citric acid percentage (Appaiah *et al*., 2015) [1].

$$T.A = \frac{\text{Titrate value (ml)} \times \text{Normality of NaoH} \times \text{milli Equivalent Wt factor of citric acid}}{\text{The volume of the sample taken (ml)}} \times 100 \quad \dots (2.1)$$

2.3.3 Total soluble solids (°Brix)

A hand refractometer was used to measure the total soluble solids (°Brix) (Atago-DR-A1). Measurements were performed at 25.0 ± 2°C. The refractometer prism was cleaned with distilled water after each analysis. (Kathiravan *et al*., 2014) [9]

2.3.4 Calorimetry

Using hunter colorimeter the color value was measured (Ultrascan VIS – Hunter Lab, U.S.A) the values L*, a*, and b* to find the colour value was selected. The light source D65 and the standard 10° angle of absorber were used (Anbarasan Rajan, 2019).

$$\Delta E = \sqrt[2]{(L^* - L^*_i)^2 + (a^* - a^*_i)^2 + (b^* - b^*_i)^2} \dots (2.2)$$

$$WI = 100 - \sqrt{((100 - L^*)^2 + a^{*2} + b^{*2})} \dots (2.3)$$

Where,

ΔE = colour difference

WI= whiteness index

L^*, a^*, b^* are the color values of the fresh coconut water sample at time zero.

L^*_i, a^*_i, b^*_i are the color values of the fresh coconut water sample at any time

2.3.5 Reducing sugar

A sample of 1 mL coconut water was taken for estimation of reducing the sugar by (ZHAO *et al*., 2008) [28]. In a test tube, one mL of DNSA solution and a threemL reduction sugar sample was added. The blank solution was prepared by adding one mL of DNS solution to three mL of distilled water. For thermal stabilization, the test tube was then immersed for 2 min in a controlled water bath. Added 1 mL of sodium sulfate solution to obtain a stable color and read the absorbance of tube 540nm against the blank.

$$Reducing\ sugars\ \% = \frac{G.F.(152) \times \text{Total volume}(50\ \text{mL})}{wt\ sample \times 10000} \dots (2.4)$$

2.3.6 Enzyme activity determination

Polyphenol oxide was determined using the method proposed by (Matsui *et al*., 2008) [12]. In a test tube, 5 mL of 0.2 M sodium phosphate buffer of pH 6 and 1 mL 0.2 M pyrocatechol was added. The test tube was then dipped into a controlled water bath for 2 min for thermal stability.1 mL of coconut water was added in the test tube and mixed adequately to measure absorbance change at 420 nm using UV Visible spectrophotometer, composed of 7.5 mL buffer and 1.5 mL 0.2 pyrocatechol concerning the blank solution.

Peroxidase activity was determined using the method proposed by (Tan *et al*., 2014) [24]. Pyrogallol 5% (w/v) solution was used as a phenol substratum. Each test consisted of 0.5 mL pyrogallol solution of 5% mixed in a 2.3 mL buffer and 0.2 ml of coconut water, and then 0.1 mL of 0.5% of H2O2 (a reaction started after the addition of H2O2). The absorbance changes were measured at 420 nm about the blank solution containing 0.3 mL 5% pyrogallol, 2.5 mL buffer, and 0.1 mL 0.5% H_2O_2.

$$Relative\ activity\ \% = \left(\frac{A}{A_o}\right) \times 100 \quad \ldots\ldots (2.5)$$

Where

A is the average thermal processing enzyme activity
and A_o is the pre-thermal processing of average initial activity.

2.3.7 Microbial analysis

Coconut water samples were diluted serially to analyze microbial counts, plate count agar for total plate count, and *E. coli* MacConey broth are selected. For total plate count at 37°C, the plate was incubated for 48 hours and *E. coli* was incubated at 25°C for 24 hours.

2.3.8 Statistical analysis

Analysis of variance (ANOVA) testing was carried out using Minitab 17 software to assess the significance (at a confidence level of 95 percent) of the effect of independent variables and their interactions on the responses. A complete factorial design has been used to estimate the effect on the response quality parameters.

3. Result and Discussion

3.1 Effect of microwave treatment on CIE Color: The color value (ΔE) of microwave treated coconut water is shown in Figure 1. From the color values, it was found that total color values were increasing with the increase in power levels and exposure time. From the figure observed that the color ΔE increased from 13.18 to 15 at 540 W for 120s, 720 W for 120s, and 900 W for 120s, respectively. The initial value of the color value of coconut water was found to be 13.18.The color ΔE value coconut water had significant ($p < 0.05$) differences during the storage period. Initial quality differences were not observed up to3rddays but color changes were observed after 5th days. In heat pasteurized juice samples, also (Victor and Orsat, 2018) [25] found color degradation.

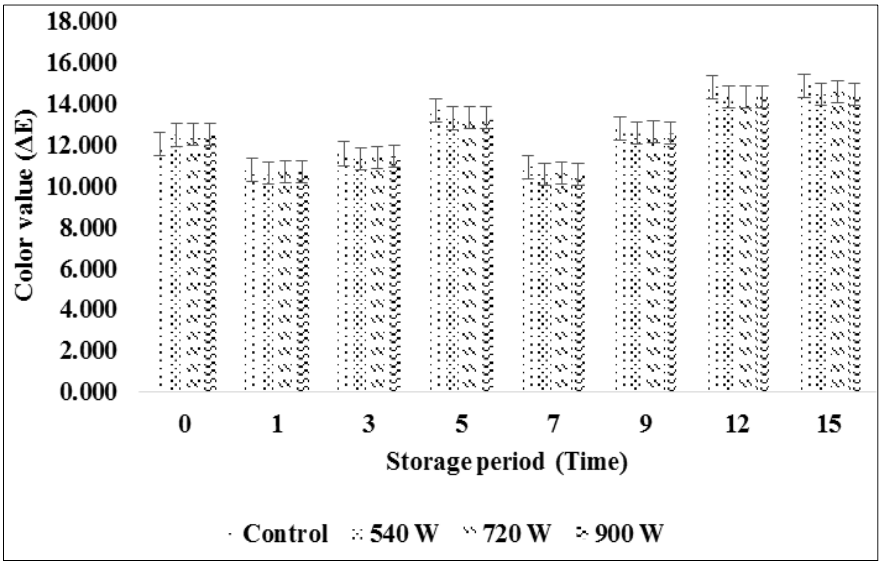

Fig 2: Color Value (ΔE) of Coconut Water during Storage

3.2 Effect of microwave treatment on pH, titratable acidity, and total soluble solids

The pH values of coconut water treated at different power levels of microwave treatments with exposure time 120sec are presented in Table 1. Usually, after storage, the pH of coconut water decreased. The pH in treatment 540 W, 720 W, and 900 W decreased from 5.4 to 4.6 and 5.4 to 4.8 and 5.4 to 4.9 respectively. It was initially observed high in these treatments after four days of storage due to removing most of the colloidal particles that could cause acidity in coconut water and then the pH decreased during storage. During the first five days of storage no significant pH of coconut water was found ($p > 0.05$) between the control and microwave processed sample. But on the ninth day of storage between the control and the processed sample a significant pH difference was observed. A similar result was obtained in the pineapple juice concentration process (Hongvaleerat *et al.*, 2008).

The acidity was expressed as a percentage of malic acid since malic acid is the dominant organic acid in coconut water. The acidity of coconut water was found to be within the range of 0.07 to 0.40 at all experimental conditions. The power level of 900 W for 120 s exposure and 720 W for 120 s exposure was on par with each other, followed by 540W for 120 s treatment. The maximum and minimum acidity values of 0.32 and 0.24 were observed in the treatment combination of 540 W for 120 s and 900 W for 120 s, respectively. The increase in acidity and a decrease in pH value could be due to the reduction in coconut water's organic acid content during heating. It was found that significant difference ($p > 0.05$) between control and microwave processed samples. Likewise, microwave treated apple juice shown changes in acidity (Canumir *et al.*, 2002) [20].

Total Soluble Solidsvaluesare in the range of 4.5 °Brix to 4.8 °Brix initially, then the values are gradually increased with time in all treatments (Table 1). The TSS of control, 900W was very high initially and then increased from 4.8 to 6.1°Brix. The TSS of treatment 540W was also initially 4.5 °Brix and on the 15th day of storage, it was observed to be 5.7 °Brix. The TSS increased from 4.8 to 5.9 °Brix for treatment T2. There was no significant change observed in the TSS of treatment T3. (Chowdhury *et al.*, 2009) [5] Made a similar observation in 10 minutes for heat-treated coconut water samples at 85°C.TSS increased from 4.5 to 5.8 °Brix, from 4.6 to 6.0 °Brix for treatment T2 and T3, respectively.

Table 1: Effect of Microwave Treatment on pH, Titratable Acidity, and Total Soluble Solids of Coconut Water

Particulars	Power level, W	Storage period (Days)							
		0	1	3	5	7	9	12	15
pH	540 W	5.42^{ab}±0.01	5.19^{f}±0.05	5.06^{f}±0.12	4.86^{a}±0.04	4.81^{e}±0.01	4.75^{d}±0.04	4.69^{c}±0.04	4.64^{c}±0.10
	720 W	5.42^{b}±0.02	5.39^{ab}±0.02	5.18^{bc}±0.03	5.09^{a}±0.02	5.03^{b}±0.02	4.94^{ab}±0.02	4.88^{a}±0.02	4.83^{a}±0.03
	900 W	5.46^{a}±0.01	5.30^{c}±0.01	5.11^{bc}±0.02	5.02^{a}±0.01	5.00^{b}±0.02	4.95^{ab}±0.01	4.92^{a}±0.02	4.91^{a}±0.03
	Control	5.40^{ab}±0.01	5.20^{e}±0.10	4.90^{f}±0.05	4.70^{b}±0.02	4.60^{f}±0.08	4.50^{e}±0.06	4.20^{d}±0.15	4.00^{d}±0.10
Titratable Acidity	540 W	0.08^{a}±0.00	0.11^{a}±0.00	0.11^{a}±0.00	0.11^{a}±0.00	0.17^{b}±0.03	0.22^{a}±0.02	0.30^{b}±0.02	0.32^{a}±0.02
	720 W	0.09^{a}±0.03	0.11^{a}±0.01	0.11^{a}±0.01	0.11^{a}±0.01	0.22^{a}±0.01	0.24^{a}±0.02	0.24^{a}±0.01	0.27^{a}±0.01
	900 W	0.10^{a}±0.00	0.11^{a}±0.00	0.11^{a}±0.00	0.11^{a}±0.00	0.17^{b}±0.02	0.21^{a}±0.02	0.22^{b}±0.03	0.24^{a}±0.03
	Control	0.07^{a}±0.00	0.10^{a}±0.00	0.25^{a}±0.03	0.29^{a}±0.01	0.37^{a}±0.01	0.32^{a}±0.02	0.37^{a}±0.03	0.40^{a}±0.01
TSS	540 W	4.6^{a}±0.06	4.8^{bc}±0.10	5.2^{b}±0.10	5.3^{ab}±0.30	5.4^{a}±0.06	5.5^{ab}±0.06	5.7^{ab}±0.06	5.7^{a}±0.10
	720 W	4.8^{a}±0.06	5.1^{b}±0.06	5.2^{b}±0.06	5.3^{b}±0.06	5.4^{a}±0.06	5.6^{a}±0.06	5.8^{c}±0.06	5.9^{a}±0.06
	900 W	4.8^{a}±0.06	5.1^{ab}±0.10	5.4^{ab}±0.06	5.5^{a}±0.10	5.7^{a}±0.06	5.8^{ab}±0.06	6.0^{a}±0.15	6.1^{a}±0.26
	Control	4.5^{a}±0.12	4.8^{a}±0.06	4.9^{ab}±0.06	4.9^{a}±0.10	5.0^{b}±0.06	5.2^{a}±0.06	5.2^{c}±0.06	5.3^{ab}±0.06

All the values in the above table are in Mean ± standard deviation form. Different letters (a, b, c d, e, and f) indicate that the averaged values are statistically different at the same level of significance ($p < 0.05$).

3.3 Effect on reducing sugar

The Reducing sugar of microwave treated coconut water is shown in Figure 2. Increasing the sugar content of all treatments during storage is observed. Reducing sugars for treatment control increased from 2.8% to 3.47% after storage. The reducing sugars were low for initial treatments T3-1.8%, and it was increased 3.33% upon storage. The value of reducing sugars for all other treatments T1, T2, and T3, increased from 1.9% to 3.40%, 2.0% to 3.36%, 1.8% to 3.33%, respectively. A thermal processing study showeda similar increasing result of reducing sugar for pomegranate juice (Yildiz *et al*., 2009) [26].

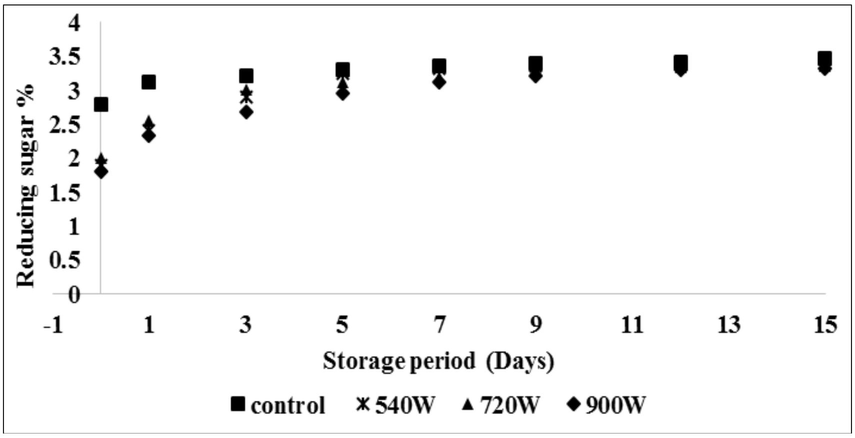

Fig 3: Effect of Microwave Treatment on Reducing Sugar

3.4 Effect on enzyme activity

The relative activity of PPO of coconut water with different treatment is presented in Figure 3. Polyphenol oxidases (PPO) are generally copper-containing oxidoreductases that catalyze hydroxylation and phenolic oxidation in the presence of molecular oxygen. The coconut PPO activity was found to be between 0.58 – 0.62 (U.mL^{-1}. Min^{-1} ° Brix $^{-1}$). The relative activity of PPO decreased with increasing the temperature and treatment time of coconut water. A similar result trend was found by (Başlar and Ertugay, 2013) [4] conducted on apple juice. Similarly, the POD activity of coconut was shown in Figure 4 and found between 0.06 to 0.078 62 (U.mL^{-1}. Min^{-1} ° Brix $^{-1}$. In general, the relative activity of POD is lesser than the relative activity of PPO (Tan *et al*., 2014) [24].

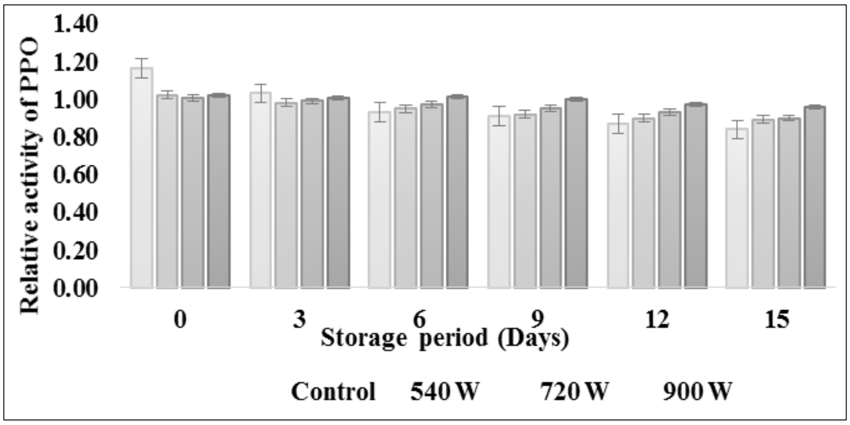

Fig 4: Effect of microwave treatment on Polyphenol oxidase (PPO)

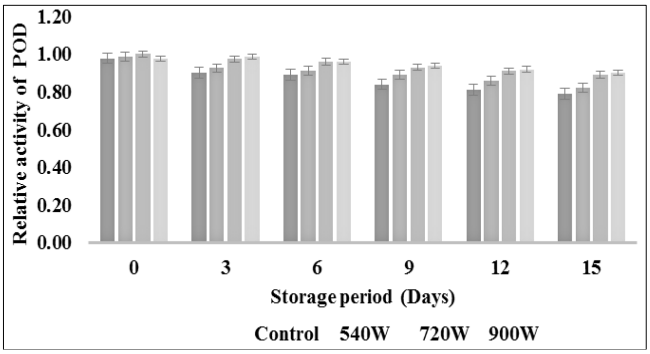

Fig 5: Effect of microwave treatment on Peroxidase (POD) value

3.5 Effect on microbiological quality

The microbial load analysis of treated juice during the storage period is presented in Table 2. *E. coli* was not found in all treatments at first.

For treatment T1, *E. coli* on the 15th day of storage, the number of *E. coli* increased to 1.02 x 10^6 CFU/10 mL. There were no *E. coli* found in treatment T3 on the 15^{th} day. Fungal count indicated no growth in all treated samples except in sample T1 in which it is increased to 0.93 x 10^6 CFU/10 mL on the 15^{th} day. (Piló *et al.*, 2009) [14] Reported similar microbial changes during storage in reconstituted stored coconut water.

Table 2: Effect of Microwave Treatment on *E. coli* and Fungal during Storage

Power levels	*E. coli* count (x 10^6 CFU / 10 mL of sample)							
	Storage period (Days)							
	0	1	3	5	7	9	12	15
T1	ND	0.14	0.21	0.35	0.39	0.43	0.54	1.02
T2	ND	ND	0.02	0.05	0.13	0.16	0.19	0.24
T3	ND	ND	ND	ND	ND	ND	ND	ND
Control	ND	1.22	2.67	2.73	2.78	2.82	2.98	3.05
	Fungal count (x 10^6 CFU / 10 mL of sample)							
T1	ND	0.10	0.31	0.38	0.44	0.62	0.71	0.93
T2	ND	ND	ND	ND	ND	ND	ND	ND
T3	ND	ND	ND	ND	ND	ND	ND	ND
Control	0	0.35	0.46	1.54	1.67	2.07	2.48	2.62

4. Conclusion

The effect of microwave heating on physicochemical properties and microbial safety *viz*. color difference, WI, pH, Acidity, TSS, total, enzyme activity, *E-Coli* of coconut water were determined at different power levels (540, 720, and 900 W), and exposure time (120 sec) of microwave heating. The results obtained from this study showed that microwave processing significantly reduces the heating time compare with the conventional method of heating and minimizes the undesirable changes during storage of treated samples. The coconut water treated at a high power level (900 W) and different exposure times have maintained quality up to 15 days under refrigerated conditions in PET bottle packaging.

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