

Original Research Article

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Effect of Ultraviolet-C Treatment on Some Physico-Chemical Properties of Tender Coconut Water

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ABSTRACT

The effect of ultraviolet (UV-C) of tender coconut water (*Cocos nucifera*) on physicochemical properties (viz. pH, total soluble solids (TSS), titrable acidity, total color difference, turbidity) were studied during this research work. The process conditions for ultraviolet treatment were sample thickness (1, 2, 3 mm), treatment time (30, 60, 90 min) and distance of sample from lamp source (8.6, 13.7, 18.6 cm). The results obtained from this study showed that the ultraviolet treatment (UV) doesn't have any significant effect on pH, TSS, titrable acidity of tender coconut water (TCW). However, the UV treatment conditions had significant effect on total color difference (ΔE^*), turbidity. Further, the results were compared with physicochemical properties of tender coconut water after thermal processing in literature. The obtained results suggested that, the loss of quality attributes is less in ultraviolet treatment as compared to other treatments. Hence, this study was concluded that, the ultraviolet treatment is good alternative methods to retention of quality attributes in coconut water.

Keywords

Tender coconut water, Ultraviolet treatment, pH, TSS, Turbidity

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Introduction

Coconut (*Cocos nucifera* L.) is one of the most important and extensively grown palm tree worldwide. The inner part of the nut (endosperm) is divided into two edible parts, white kernel and clear liquid (Coconut water/juice). Coconut water widely consumed as a beverage usually comes from immature coconut fruit which is at a tender stage and referred as tender coconut water. The tender coconut water is considered as a natural health drink due to its unique characteristics (Debmandal *et al.*, 2011). Its sugar content and mineral composition makes it an ideal rehydrating and refreshing drink (Campbell *et*

al., 2000). Tender coconut water (TCW) is considered as low acid and high water activity beverage which contains carbohydrates, proteins, fats, and minerals (Campos *et al.*, 1996 and Krishnankutty *et al.*, 2005). The physicochemical and nutritional properties of TCW can vary based on variety and geography (Yong *et al.*, 2009). The TCW is rich source of nutrients. It can be used as best medicine for diseases like fever, heartburn, dengue etc. Consumption of coconut water prevents the formation of kidney stones, high blood pressure, and diabetes. It is also used for increase metabolic rate, weight loss,

strong bones and teeth, facilitates digestion, helps with muscle cramp, prevents and treats dehydration etc. The antioxidants which are present in TCW reduce the swelling in hands and legs.

Market for tender coconut water is increasing considerably due to its medicinal, nutritional and sensory properties. Further market for processed bottled tender coconut water also increasing to reduce transport cost and easily available in all locations throughout a year. However, there is a challenge for developing process to ensure that the product is available with safety and high nutritional and sensory quality.

Generally, the tender coconut water present inside the fruit is shelf sterile and stable for few days (Yong *et al.*, 2009), but shelf life of extracted tender coconut water is very less. The spoilage of extracted TCW mainly due to the presence of enzymes, belonging to oxidase family (Polyphenol oxidase and Peroxidase), that in contact with atmospheric oxygen. The oxidative enzymes have high thermal resistance and their activity leads to yellow, brown or even pink colouring during storage, even under refrigeration.

Polyphenol oxidase (PPO) and Peroxidase (POD) are widely detected in many fruits and vegetables and are closely linked to enzymatic color changes with consequently loose on sensorial properties (Campos *et al.*, 1996).

According to some food technologists, Polyphenol oxidase is indirectly responsible for fruit and vegetables enzymatic browning, it catalyzes two types of oxidative reactions. Such as hydroxylation of monophenols to o-diphenols, and the oxidation of this last one colorless compound to highly colored o-quinones. Presently thermal treatment is most commonly applied for inactivating enzymes in coconut water. But the thermal treatment

leads to destruction of heat sensitive nutrients which restricts its application for processing of coconut water. Besides the loss of nutrients, it also shows a detrimental effect on color and flavor.

Alternative methods are high pressure application, pulsed electric field, irradiation, and aseptic packaging. However, there are some disadvantages of these techniques in terms of cost, loss of ascorbic and some other quality attributes.

Considering these limitations of other techniques, UV-Radiation can be used as an alternative method for processing and preservation of TCW. This process does not produce chemical residues (Canitez, 2002). Besides, it is a low-cost operation and effective against many microorganisms (Bintsis *et al.*, 2000) and enzymes.

UV light is the part of electromagnetic spectrum with wavelengths ranging from 100-400 nm. UV light is traditionally subdivided into three categories (viz. UV-A, UV-B and UV-C). UV-C is used for surface disinfection of different fruits and other processing equipment. Application of UV light on various liquid foods like apple cider, orange juice, grape juice, milk and honey have been reported recently.

Germicidal properties UV-C is due to the absorption of the UV-light by DNA, which causes formation of thymine dimer in the same DNA strand (Miller *et al.*, 1999). Due to this, the DNA transcription and replication is blocked, which compromises cellular functions and leads to cell death (Miller *et al.*, 1999).

The penetration depth of UV light in coconut water is more because of the UV absorption coefficient of coconut water is less, thus it facilitates UV rays to pass through it. By considering all above factors, the present

study was aimed to study the effect of UV-C treatment on some physicochemical properties of tender coconut water.

Materials and Methods

Coconut water

Green coconut fruits of approximately same size having 6-8 months maturity contained coconut flesh (jelly like) less than 2 mm and without any visible damage on outside were purchased from local market at IIT Kharagpur. Surface of coconut husk was properly cleaned with distilled water followed by 1% sodium hypochlorite sanitise solution (Walter *et al.*, 2009). After the coconuts were placed in laminar flow UV light chamber for 30 min to make coconuts free from surface contamination (Fig. 1).

Coconut water was manually extracted from coconut fruit using free washed and sanitized sharp stainless steel and filtered through muslin cloth. The filtered coconut water obtained from several fruits (4-5 coconut fruits having same maturity level) was mixed in a glass beaker. The coconut water was filled and packed in LDPE (low density polyethylene) pouches and immediately stored at -18 °C before use. All the coconut water prepared was processed on the same day of extraction.

Chemicals and reagents

All the chemicals and reagents used in the study were analytical grade and procured from Merck, India and Sigma-Aldrich, Germany.

Ultraviolet treatment of coconut water

Continuous UV light apparatus was designed at IIT Kharagpur during this study (Fig. 2). The system was designed such that distance of sample from lamp source can be varied.

Three 18 W low pressure mercury vapor UV lamp which emits the UV-C light in the wave length ranges from 200-300 nm were mounted at the top of treatment chamber. A manually operated switch was used to control the treatment time.

Coconut water was poured in 150 mm standard size petri plates. Petri plates having coconut water was placed at the center of holder platform (used to maintain the distance of sample from lamp source). Sample thickness was maintained by changing the volume of coconut water in petri plates. Coconut water was treated at different treatment conditions viz. sample thickness (1, 2, 3 cm), treatment time (15, 30, 45, 60, 75, 90 min) and sample distance from lamp source (8.6, 13.7, 18.6 cm). To prevent the exposure of UV light to human skin, a cover was placed in front of the system.

Experimental design

Full factorial design with 3 replications was followed throughout the experiment. The independent variables viz. Treatment time (t – 15, 30,45,60,75 and 90 min), Distance from lamp source (H – 8.6, 13.7, 18.6 cm) and Sample thickness (x – 1, 2, 3 cm) were selected with three levels of each of independent variables and their combinations had been investigated for each attribute. After each experiment, the physicochemical properties viz. pH, TSS, Color, Titrable acidity, Turbidity, Transmittance, Protein content were analyzed to know the effect of treatment on its.

Physicochemical analysis of tender coconut Water

Measurement of pH

pH of the coconut water was measured using a digital pH meter (Model: Adwa AD8000) as shown in figure 2(a) in triplicates. The probe

of pH meter was inserted into coconut water and the stable reading obtained was considered as the final pH value.

Measurement of total soluble solids (TSS)

Total soluble solids (TSS) indicates the sweetness of coconut water. Total soluble solids (TSS) of coconut water was determined using a digital handheld refractometer (Model: PAL-1; Make: Atago, Japan) as shown in figure 2(b), having a range of 0-53% according to the methods proposed by Ranganna (1991). Before measurement of TSS of sample, the refractometer was calibrated using double distilled water.

A drop of the coconut water was placed on the sample slot refractometer and the TSS of the sample was recorded and expressed in °Brix.

Measurement of titratable acidity (TA)

Titratable acidity (TA) in the sample was determined by titration method proposed by Ranganna (1991). Briefly, 10 mL of coconut water was taken and diluted to 30 mL with distilled water.

10 mL diluted coconut water was taken for titration, mix 2-4 drops of 1% phenolphthalein indicator and titrated against 0.1 N NaOH solution. Titer values were noted and titratable acidity was expressed as malic acid percentage since malic acid is the dominant organic acid in coconut water (Santoso *et al.*, 1996; Yong, Ge, Ng, & Tan, 2009).

$$T.A \text{ (\% malic acid)} = \frac{\text{Titre value} * \text{Normality of NaOH} * \text{milli Equivalent weight factor of malic acid} * 100}{\text{Vol. of sample taken}} \dots \dots \dots (1)$$

Where

Millequivalent of malic acid = 0.067

Measurement of color

Color of coconut water was measured based on CIE color parameters L* (0-100, Black-Lightness), a* (positive values – red, negative values- green and 0 is neutral) and b* (positive values – yellow, negative values- blue and 0 is neutral). Portable colorimeter (Model: Spectro-guide 45/0 gloss; Make: BYK Gardner, Germany) was used to measure the color parameters [Fig. 2(c)]. The colorimeter was calibrated using green, white and black tiles. Results were expressed as the mean of three measurements. The overall color difference (ΔE^*) can be calculated using Equation. (2).

$$\Delta E^* = \sqrt{(L_0^* - L_1^*)^2 + (a_0^* - a_1^*)^2 + (b_0^* - b_1^*)^2} \dots (2)$$

The subscript ‘0’ represents the color value for reference sample and subscript ‘1’ represents the color value for the sample being analyzed.

Measurement of turbidity and transmittance

Turbidity was determined using a spectrophotometric method at 610 nm proposed by Campos *et al.*, (1996). Absorbance of the sample was read in relation to distilled water and the transmittance and respective turbidity were calculated according to equations highlighted below

$$\text{Transmittance (T)} = 100 * 10^{-Abs} (3)$$

Where

Abs is the adsorption at wavelength of 610 nm.

$$\text{Turbidity} = 100 - T (4)$$

Where

T’ is the transmittance at wavelength of 610 nm.

Data analysis

Analysis of variance (ANOVA) test was conducted using Design expert version 7.0.0 software (State-Ease Inc., Minneapolis, USA) to evaluate the significance (at 95% confidence level) of the effect of independent variables and their interactions on the responses.

A full factorial design was used to estimate the effect of independent variables (Treatment time, sample thickness and distance sample from lamp source) on responses (pH, TSS, total color difference, titrable acidity, turbidity, and transmittance).

Optimization of process parameters

RSM was applied to the experimental data using Design expert version 7.0.0 software (State-Ease Inc., Minneapolis, USA). The critical responses were screened out Based on the effect and importance of responses. The optimization was targeted for the minimal changes in physicochemical properties in coconut water.

Results and Discussion

Compositions of raw tender coconut water

The physicochemical properties of TCW were analyzed before treatment. The compositions of TCW varied from fruit to fruit depending upon variety and maturity of fruit (Jackson *et al.*, 2004; Hahn *et al.*, 2012; Tan *et al.*, 2014).

Although there was important initial difference exist in physicochemical properties of TCW between different varieties of fruit. But for comparison these parameters kept as constant for whole experiment. The compositions of fresh TCW were measured and presented in table 1.

Effect of ultraviolet treatment on physicochemical properties of TCW

Effect on pH

The pH values of TCW during Ultraviolet treatments at different conditions were presented in figure 3(a-c). Generally, the pH plays an important role in phenomenon such as enzyme activity, protein denaturation and microbial inactivation kinetics and most microorganisms show increased susceptibility and inability to recover from sub-lethal injuries at low pH values. The pH of TCW at all experimental conditions were found to be in the range of 4.5 to 4.8. Similar values of pH were found to be within the reported range in the literature (Tan *et al.*, 2014).

Further, from the ANOVA data it was noticed that the ultraviolet processing conditions of TCW had a significant effect on pH ($p < 0.0001$). The ultraviolet treatments at different distances such as 8.6, 13.7 and 18.6 cm were shown negligible changes in pH values at different time intervals (0.0-90.0 min). Further, at different thickness levels viz., 1, 2 and 3 mm at a particular distance and time interval for example 8.6 cm at 90 min showed slight differences in pH values.

In addition, during UV treatment the pH varied from 4.62-4.7 with a deviation of ± 0.04 with respect to any replication. The UV light system might not severe enough to cause the release of H^+ ions from coconut water and hence the pH of coconut water remained constant after ultraviolet treatment. In addition, the slight variation of pH can be considered as experimental error. Similar kind of studies related to the UV-C effect in other commodities such as apple juice, pineapple juice and lemon-melon juice were reported by Caminiti *et al.*, (2010), Falguera *et al.*, (2011) and Nociet *et al.*, (2008), Shamsudin *et al.*, (2014), Kayaet *et al.*, (2015).

Effect on TSS

The TSS values of UV light processed TCW at different conditions were presented in figure 4 (a-c). In general, Total soluble solids (TSS) indicated as the sweetness of TCW and were found in the range of 4.6 to 5.6 °Brix. The obtained values of TSS were found to be within the reported values in the literature (Tan *et al.*, 2014). From ANOVA data it was showing that the ultraviolet treatment conditions had significant effect ($p < 0.0001$) on TSS of TCW. However, the maximum deviation obtained in TSS after ultraviolet treatment is ± 0.3 with respect to any replication. The ultraviolet treatments at different treatment time interval (0.0-0.90 min) showed slight difference in TSS. However different distances such as 8.6, 13.7 and 18.6 cm were shown negligible changes in TSS values. Further, at different thickness levels viz., 1, 2 and 3 mm at a particular distance and time interval for example 8.6 cm at 90 min showed slight differences in TSS values. TSS represents soluble sugars. Sugars such as glucose, fructose does not absorb UV-C in the range of 240-360 nm. Hence there will be no effect of UV-C treatment on TSS of TCW. So far there is no review available to compare the TSS value of TCW after ultraviolet treatment. However, Similar kinds

of studies related to the UV-C effect in other commodities such as apple juice, Pineapple juice and lemon-melon juice were reported by Caminiti *et al.*, (2010), Shamsudin *et al.*, (2014), Kaya *et al.*, (2015), Falguera *et al.*, (2011). The variation in TSS can be attributed to experimental error.

Effect on titrable acidity

The Titrable acidity values of UV light processed TCW at different conditions were presented in figure 5 (a-c). In this study the Titrable acidity of TCW was expressed as malic acid percentage since malic acid is the dominant organic acid in tender coconut water (Yong *et al.*, 2009). Titrable acidity of coconut water was found to be in the range of 0.072 to 0.076 (% malic acid). From ANOVA data it was showing that the ultraviolet treatment conditions had not significant ($p > 0.0001$) effect on Titrable acidity of TCW. However, the results show that there are slight higher values of Titrable acidity after UV treatment of TCW with respect to control (Raw TCW). At different UV light treatment conditions there is a negligible change in Titrable acidity value. The reason for such kind of behavior is might be due to the UV light doesn't cause to release the H^+ during the treatment.



Fig.1 Extraction of tender coconut water

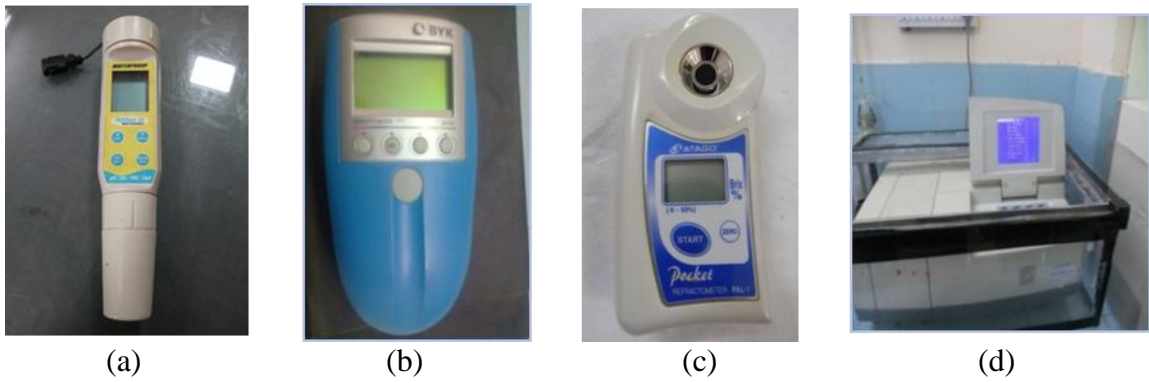


Fig.2 Instruments for measurement of physicochemical properties of TCW a) pH meter b) Colorimeter c) Digital Refractometer d) UV-visible spectrophotometer

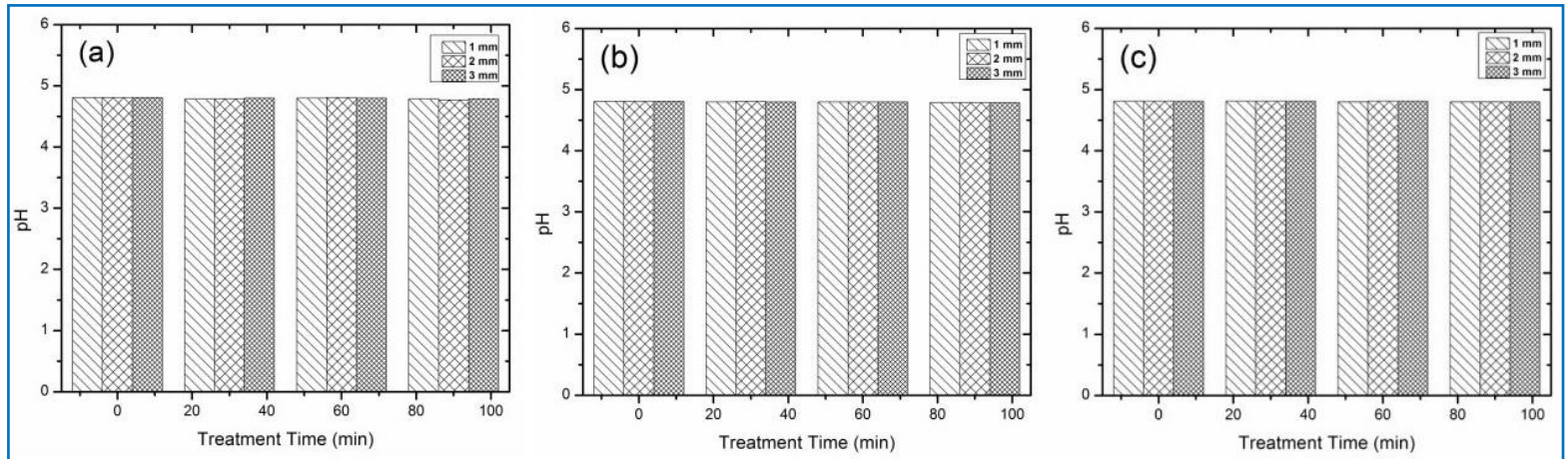


Fig.3 Effect of different treatment conditions on pH of TCW (a) UV, 8.6 cm (b) UV, 13.7 cm (c) UV, 18.6 cm

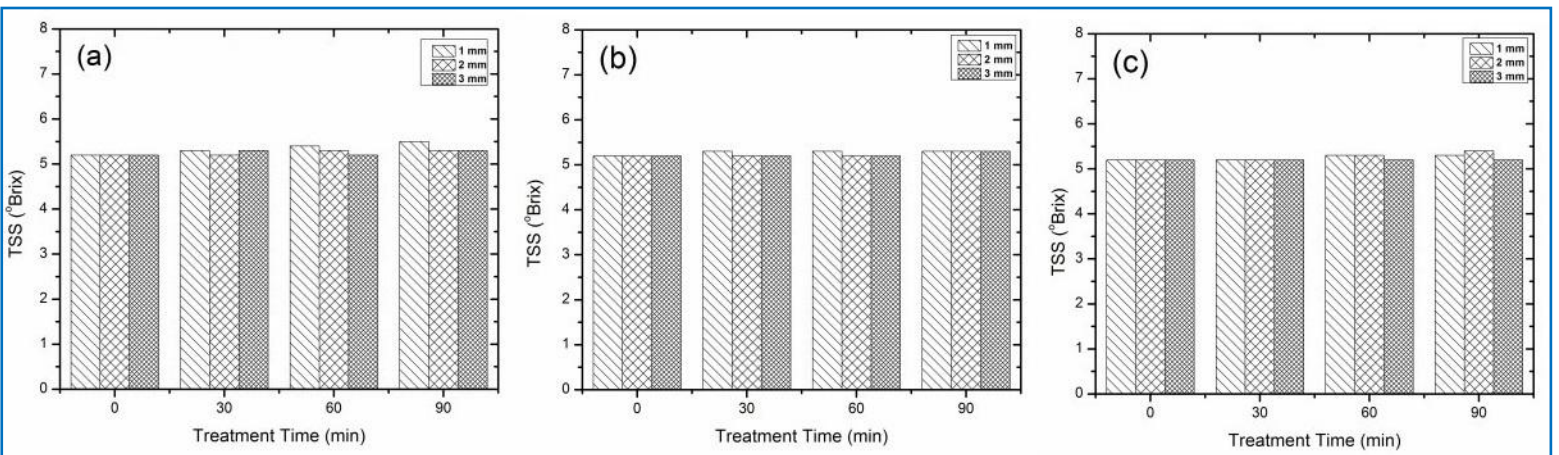


Fig.4 Effect of different treatment conditions on TSS of TCW (a) UV, 8.6 cm (b) UV, 13.7 cm (c) UV, 18.6 cm

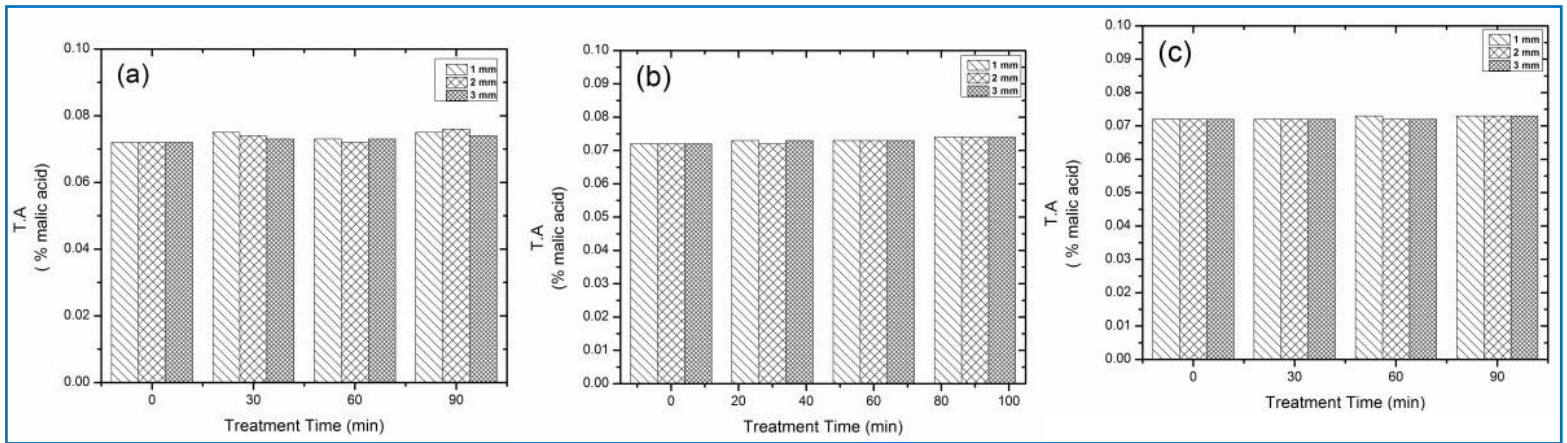


Fig.5 Effect of different treatment conditions on titrable acidity of TCW (a) UV, 8.6 cm (b) UV, 13.7 cm (c) UV, 18.6 cm

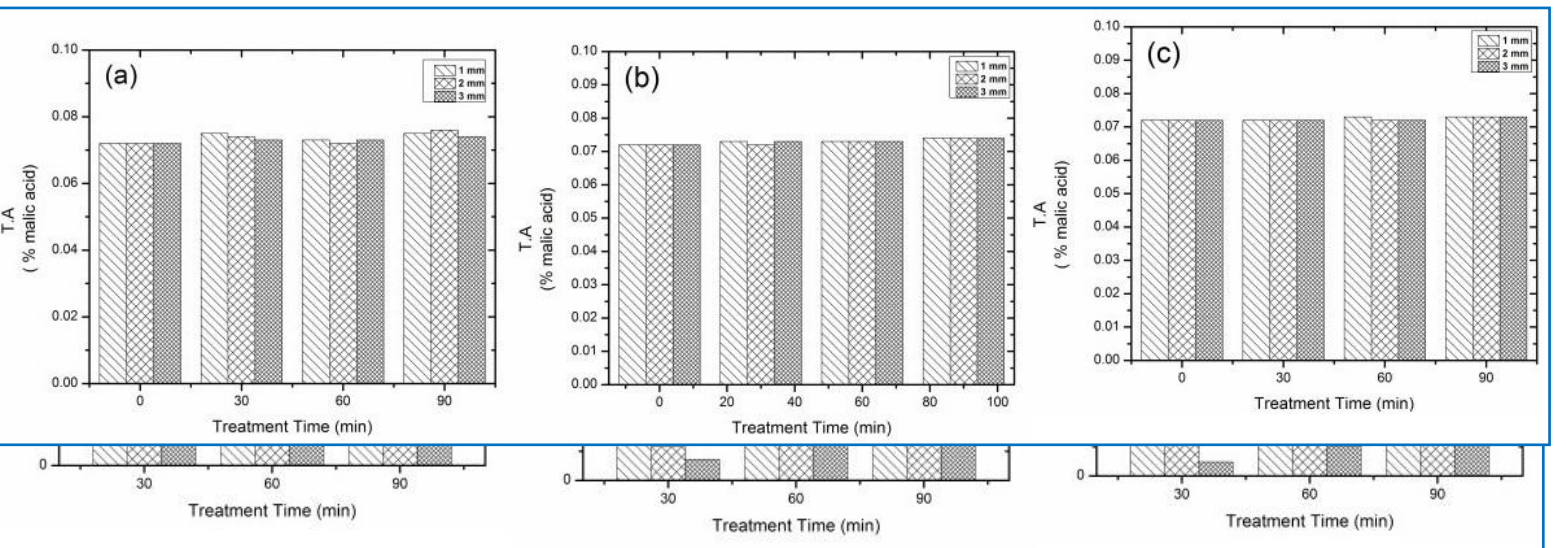


Fig.6 Effect of different treatment conditions on total color difference of TCW (a) UV, 8.6 cm (b) UV, 13.7 cm (c) UV, 18.6 cm

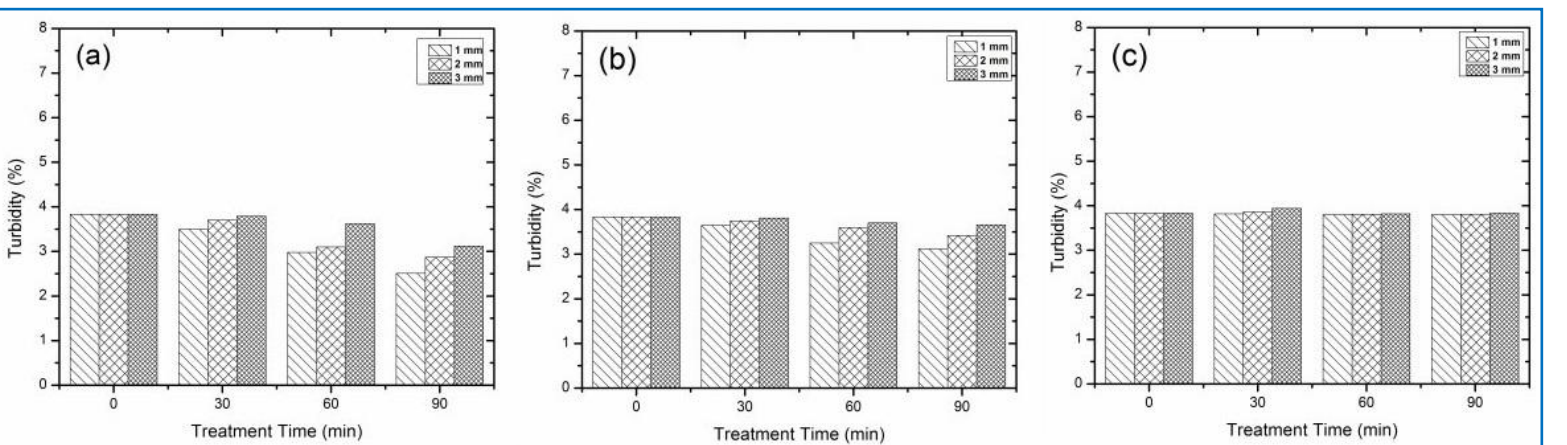


Fig.7 Effect of different treatment conditions on turbidity of TCW (a) UV, 8.6 cm (b) UV, 13.7 cm (c) UV, 18.6 cm

Table.1 Physicochemical characterization of tender coconut water

Parameters	Value
pH	4.8 ± 0.15
TSS (°Brix)	5.2 ± 0.16
Titration acidity (%malic acid)	0.07 ± 0.01
L*	29.37 ± 0.35
a*	0.01 ± 0.006
b*	0.53 ± 0.08
Turbidity (%)	3.6 ± 0.3
Transmittance (%)	96.4 ± 0.7

Note: Values reported as mean ± standard deviation (N = 12).

Effect on total color difference

The total color difference values of UV light processed TCW at different conditions with respect to control (unprocessed tender coconut water) were presented in figure 6 (a-c). The measurement of color is important for the quality assessment of juice. The total color difference was calculated based on L*, a*, b* values. From ANOVA data it was showing that the ultraviolet treatment conditions had significant ($p < 0.0001$) effect on total color difference in TCW. The ultraviolet treatments at different distances such as 8.6, 13.7 and 18.6 cm were showed slight changes in total color difference at different time intervals (0.0-90.0 min). Further, at different thickness levels viz., 1, 2 and 3 mm at a particular distance and time interval for example 8.6 cm at 90 min showed negligible changes in total color difference. The reason for such kind alternations with thickness and distance were not understood but largely attributed to the fact that the alteration of thickness might causes the penetration of UV light through the sample whereas alterations of distance not showed much effect. The sample which is nearer to the lamp source and having less thickness will receive more energy (Bolton, 1991). The changes in color after ultraviolet irradiation is due to that the UV radiation impairs some of the pigments present in the juice, either initially present or the ones formed later by

the rapid action of polyphenol oxidase (melanins) as well as the Maillard reaction between sugars and amino acids (melanoidins). The maximum changes color difference was observed to be 3.18 after ultraviolet treatment. However the total color difference obtained in this study was higher than the study conducted by Falguera *et al.*, (2006) on apple juice. It may due to the variation in properties of sample and treatment conditions.

Effect on Turbidity

The Turbidity values of UV light processed TCW at different conditions were presented in figure 7 (a-c). Generally, turbidity is the cloudiness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye. It can be defined as a measurement of the degree to which light is scattered by suspended particles and soluble solids in TCW. The turbidity of TCW was found in the range of 3.6 to 3.8 %. The obtained values of turbidity are found to be within the reported values in the literature (Tan *et al.*, 2014).

From ANOVA data it is showing that the ultraviolet treatment conditions (such as sample thickness, treatment time and distance of sample from lamp source) had significant ($p < 0.0001$) effect on turbidity of TCW. However the maximum decrease in turbidity

after ultraviolet treatment is 1.32 % with respect to any replication. So far there is no review available to compare the Turbidity of TCW after ultraviolet treatment. However, similar kinds of studies related to the UV-C effect in other commodity such pineapple juice was reported by Shamsudin *et al.*, (2014). The decrease in turbidity may be because of the reduction of yeast and molds counts after ultraviolet treatment. Yeast and mould can contribute to the turbidity of fluids and if there is a decrease in number then the turbidity is speculated to demonstrate a decrease (Cantez, 2012). Besides that, Digiacomio and Gallagher (1959) had studied that spoilage by yeast and bacteria has induced sediment and turbidity in soft drink that contain juice.

In conclusion, effect of ultraviolet (UV-C) of tender coconut water (*Cocos nucifera*) on physicochemical properties (viz. pH, total soluble solids (TSS), titrable acidity, total color difference, turbidity) were studied during this research work. The process conditions for ultraviolet treatment were sample thickness (1, 2, 3 mm), treatment time (30, 60, 90 min) and distance of sample from lamp source (8.6, 13.7, 18.6 cm). The results obtained from this study showed that the ultraviolet treatment (UV) doesn't have any significant effect on pH, TSS, titrable acidity of tender coconut water (TCW). However, the UV treatment conditions had significant effect on total color difference (ΔE^*), turbidity. Further, the results were compared with physicochemical properties of tender coconut water after thermal processing in literature.

The obtained results suggested that, the loss of quality attributes is less in ultraviolet treatment as compared to other treatments. Hence, this study was concluded that, the ultraviolet treatment is good alternative methods to retention of quality attributes in coconut water.

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