Thermal processing of tender coconut water: A colour preservation approach

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Abstract

In this study, major physicochemical properties like total solid, total soluble solid, reducing sugar %, invert sugar%, ascorbic acid%, titratable acidity, pH, sodium, potassium, sweetness, and colour based properties, were studied. The result reflected solid to water ratio of 5:95, with high potassium content and other parameter with a desirable limit. The effect of thermal processing on colour based changes in tender coconut water was examined between 50 to 90°C and time of exposure for 60 sec to 120 sec. The colour change was investigated using a 2^2 experimental design. Further kinetic study of colour change was also performed at the best result obtained from above design. Kinetic studies showed that the thermal inactivation of colour development at 90°C, followed first-order kinetics. The reaction rate constant (k), Decimal reduction time (D_{90}) of thermal inactivation of colour development, were 0.004 Sec^{-1} and 221.22 Sec. respectively.

Keywords: Thermal Processing, Tender coconut water, Colour development, Kinetics.

1. Introduction

Coconut water, as a tropical fruit juice, is highly prized and consumed in tropical area since it is tasty and has desirable nutritional and healing attributes. Coconut (*Cocos nucifera L.*) fruit is filled with the sweet clear liquid “coconut water” when the coconut is about 5 to 6 months old. Coconut water contains a variety of inorganic ions (Arditi, 2000) and these ions contribute to the therapeutic value inherent in coconut water. As the basic ion composition of coconut water can replenish the electrolytes of the human body excreted through sweat, such as sodium, potassium, magnesium and calcium, it can serve as an effective rehydration drink (Saat *et al.,* 2002). The concentration of these electrolytes in coconut water generates an osmotic pressure similar to that observed in the blood, and it also does not affect haemostasis (plasma coagulation) (Pummer *et al.,* 2001). As a result, coconut water can be used as a short term intravenous hydration fluid under certain emergency situations (Cambell, 2000). Interestingly, Anurag and Rajamohan (2003) showed that coconut water has cardio protective effects in experimental myocardial infarction induced in rats and this was probably attributed to the rich content of mineral ions in coconut water, especially potassium.

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Like other fruit and vegetable products, tender coconut water also suffers from colour based quality deterioration (Campos *et al.,* 1996). Natural phenolics compounds in fruit and vegetables in the bearing of a Polyphenoloxidase (PPO) and oxygen are oxidized and that subsequently polymerizes to brown pigments known as quinone (Queiroz *et al.,* 2011). This browning process leads also to a change in flavour and a decrease in nutritional quality, particularly ascorbic acid (Vámos-Vigyázó 1981; Queiroz *et al.,* 2011). Previous studies have also demonstrated that enzyme responsible for colour change is a function of solute content in coconut water (Matsui *et al.,* 2007).

The most significant controller, that influence the pace of the enzymatic browning of fruit and vegetables are the concentrations of both active PPO and phenolic compounds present, the pH, the temperature and the oxygen availability of the tissue (Martinez & Whitaker 1995; Friedman 1996; McEvily *et al.,* 1992). In general, exposure of PPO to temperatures of 70–90 °C destroys their catalytic action (Vámos-Vigyázó 1981). Thermal processing is one of the most widely used preservation method in food industries because high temperature could lead to the inactivation of both microbial and enzymatic activities (Aguiar *et al.,* 2012). However, kinetic approach for effect of storage on colour based changes has not yet been addressed. Therefore, current study was focused to investigate the physicochemical properties of tender coconut water and to evaluate the effect of temperature - time combination on colour change followed by determination of kinetic parameter associated with it.

2. Materials and methods

The tender coconuts were cut with a sharp sanitized stainless steel knife and all the coconut water collected was mixed thoroughly in a sterilized container inside laminar air flow, after thorough washing of surface with water. The above tender coconut water sample collected was taken for further analysis. Physicochemical properties of the extracted water were determined as per standard procedure described below.

Further, 2^2 experimental design was used to assess the effect of temperature and time combination of colour development, in tender coconut water. For above experimental design the temperature and time ranges from 50 to 90°C (low level to high level) and 60 sec to 120 sec (low level to high level), respectively. The low level and high levels were denoted with –ve and +ve sign. In this design, treatment was performed for 60 Sec and 120 Sec at both 50 and 90°C. Further the kinetic study was performed at suitable temperature obtained from above design.

2.1 Physicochemical properties

2.1.1 Determination of pH

The pH of tender coconut water was measured using pH meter (model: Eutech), standardized with buffer solution of pH 4.0, 7.0 and 9.0.

2.1.2 Total solid

The total solid of the tender coconut water was estimated by evaporating the solvent in a convection oven, to complete dryness. After drying the final weight of residual solid was taken and percentage of total solid was determined (Ranganna, 1997).

Total Solid% = (residual solid / wt of sample taken) × 100.

2.1.3 Brix estimation and Specific gravity

Brix of a solution shows its total soluble solid content. It can be determined by using brix and specific gravity hydrometer. For the analysis 250 ml sample was taken into a glass cylinder. Then it was thoroughly shaken to make a homogeneous suspension. After that the brix hydrometer and specific gravity hydrometer were dipped into it separately and the degree brix and specific gravity were noted. Then the temperature corrections were done from the brix and specific gravity table. (Ranganna, 1997).

2.1.4 Determination of titratable acidity

Total titratable acidity was, determined by using 0.1 N NaOH and phenopthaline as indicator and expressed as %citric acid (eq.wt = 64) (Ranganna, 1997).

2.1.5 Determination of Brix: Acid Ratio

The brix: acid ratio is the ratio of °brix to the grams of anhydrous citric acid in 100 g of juice or concentrate. The ratio was determined by dividing the degrees Brix of a sample by the percentage of titratable acidity of the sample, and expressed nearest to the first decimal place (Ranganna, 1997).

2.1.6 Ascorbic acid estimation

The 2, 6-Dichlorophenol-Indophenol dye, which is blue in alkaline solution and red in acid solution, is reduced by ascorbic acid to a colourless form. For the analysis 2 ml of coconut water sample was taken and acidified with HPO3 to final volume of 10 ml. Then it was titrated with the standard dye to a pink end-point (should persist for at least 15 sec). The volume of dye consumed was further used for mg % ascorbic acid determination. (Ranganna, 1997).

2.1.7 Chloride estimation

Chloride content was determined by Mohr's method. When water containing chlorides is titrated with silver nitrate using potassium chromate as indicator, silver chloride is quantitatively precipitated, and at the end point red silver chromate is formed. One ml of potassium chromate

indicator was added to a 100 ml of coconut water and it was titrated with standard silver nitrate solution (0.141 N) to a pinkish yellow end point. Blank was 100 ml of distilled water titrated similarly (Ranganna, 1997).

2.1.8 Reducing sugar estimation

Fehling solution A & B 5ml each was pippeted into 250 ml conical flasks. It was heat to boil and then volume of coconut water, required to reduce the Fehling's solution, was added then 3 drops of the methylene blue solution was added, taking care not to allow it to touch the side of the flask. Then the burette was filled with the coconut water and titration was further proceed until the indicator is completely decolourized. At the end point, the boiling liquid assumes the brick-red colour of precipitated cuprous oxide, which it had before the indicator was added. The volume of the coconut water required was noted (Ranganna, 1997).

Reducing Sugar % = F.F x 100 × DF/VC

(F.F = Fehling factor DF = dilution factor VC= Volume Consumed)

2.1.9 Inverts Sugar, Sucrose and Total sugar estimation

Fifty ml of the coconut water sample was taken. Then 25 ml water and 10 ml of 12N HCL added to it. After that it was kept at 70 deg. C for 10 min for inversion. After inversion it was cool down to room temperature and neutralize by 6N NaOH with phenolphthalein as an indicator. The total volume was made up to 100 ml with water. The above solution was titrated against Fehling A & B solution with Methylene blue as an indicator. The end point was brick red colour (Rangana, 1997).

Invert Sugar % = F.F x 100 × DF/VC

(F.F = Fehling factor DF = dilution factor VC= Volume Consumed)

% Sucrose = (% of Total invert sugars - % of Reducing sugars originally present) × 0.95.

% Total Sugars = (% of Reducing sugars + % of Sucrose).

2.1.10 Determination of colour

Colorimetric was performed using a Hunter Lab colour Flex (ColourflexEZ model) according to the CIE Lab scale. The instrument was calibrated prior to use using white and black tile, supplied with the system. The colour measurement resulted in CIE Lab values for lightness (L, L = 100 is white and L = 0 is black), redness (a, + red to - green component) and yellowness (b, + yellow to - blue component). The sample was illuminated with D65-artificial daylight incident at standard angle of 10°C.

2.1.11 Mineral content (Na+ and K+)

The Na+ and K+ concentration was determined by using Flame photometer (Model: Systronic 128). The analysis was done after calibration of the instrument with standards ppm solution of sodium and potassium separately (Ranganna, 1997).

2.1.12 Total phenolics content (TPC)

TPC of coconut water were determined using Folin–Ciocalteu method with some modifications. Coconut water (1 ml) was placed in a 100 ml volumetric flask followed by 70 ml of distilled water and 5 ml of Folin & Ciocalteu's phenol reagent (10 times dilution). Mixture was incubated for 5 min at room temperature before adding 15 ml of 7.5% (w/v) sodium carbonate and top up to 100 ml with distilled water. Mixture was incubated for 2 h at room temperature. Measurement of absorbance was carried out in UV-10, Thermo UV–Vis spectrophotometer at wavelength of 765 nm. TPC was expressed as Gallic acid equivalents (GAE) using units of mg/L (mg GAE/L).

2.2 Thermal treatment

Total four sets of sample were taken for thermal treatment as per experimental design. An amount of 50 ml tender coconut water was taken into 100 ml volumetric flask for each treatment combination. The flasks were subjected to thermal heating by immersing in water bath with temperature control. At each temperature, two different heating times; 60 Sec and 120 Sec were tested. When each specific heating time was reached, flasks were taken out from the water bath and immediately immersed in the ice water in order to stop the effect of thermal treatment. Then the flasks were incubated for 48 hr at 37±2°C and allowed for colour development.

2.3 Kinetic colour inactivation

Determination of kinetic parameter for colour inactivation was done by taking b* value (Yellowness), as reference. The rate constant was determined by plotting log b* against holding time at 90°C. Further D value was calculated using the following equation: D = 2.030/k, where D value is the time in seconds required to deactivate 1 log cycle (90%) of reaction under isothermal conditions.

3. Result and discussion

3.1 Physicochemical properties of tender coconut water

The basic physicochemical properties of tender coconut water were analyzed and represented in Table-1. The results reveals the average volume of tender coconut water to be 188 ml (ranging from 156 ml to 220 ml) per tender coconut, which was lower than reported earlier (Santoso *et al*., 1996; Campbell-Falck *et al*., 2000; Awua *et al*., 2011). That might be due to difference in location, cultivation or maturity stage of the nut. The temperature of raw

extracted tender coconut water was found to be 17.8°C (ranging from 16°C–18°C), which is far lower than room temperature. This low temperature might be the reason behind cooling effect of coconut water in consumer's body. Apart from this brix (total soluble solid), pH and acidity were found to be 5.04, 5.4 and 0.15 respectively, which satisfy the investigation result reported earlier by many researchers along with prescribed drinking coconut water standard by FAO. As the suspended solid in coconut water was almost negligible, the brix can be taken as total solid and result of total solid (4.85%) determined by convection drying method was also approximately to brix value. During maturation total sugar concentration decreases and sucrose concentration gradually increases as a result total solid also changes (Santoso *et al.,* 1996).

The total sugar concentration obtained in tender coconut water was 4.53% (reducing sugar = 4.24%, sucrose = 0.29%) as it was 7–8 month old. The information regarding maturation stage of sample was collected from cultivation farm. The brix to acid ratio represents sweetness, which is an important factor during harvest according to previous research report 7–8 month maturity was found suitable and in this study at this stage brix to acid (sweetness) ratio was found to be 32.85±0.5. As coconut is a coastal agri-product, its chloride concentration was important and in this study chloride in tender coconut water was not detected, which is also matches with study made by (Yong *et al.,* 2009). Among antioxidants ascorbic acid was estimated and found to be 0.18 mg per 100 ml of tender coconut water, which is nearer to data available in USDA Nutrient Database. Coconut water is well known because of its abundant k concentration and lower Na concentration. The data obtained for k and Na were 3113 ppm and 163 ppm respectively. The Na+ concentration was slightly higher and k concentration was found similar as reported earlier (Prades, Alexiav Dornier *et al.,* 2012). Table 1 also reveals the colour based property of raw tender coconut water by Hunter Lab colour Flex with CIE scale and parameter L* (Darkness-lightness), a* (greenness-redness), b* (blueness-yellowness). The data found for L*, a*, b* were 35.34, -0.57 and 2.80 respectively. These above data of colour configuration imparts a natural coconut water colour as it looks to consumer's eye manually. However, effect of storage on colour of tender coconut water under ambient condition for 48 h was reported as L*, 35.23±1.48; a*, 2.81±0.135; b*, 2.83±0.92 (Purohit *et al.,* 2016). Such difference is might be due to oxidative enzymatic browning.

3.2 Effect of thermal processing on colour development in tender coconut water

In the temperature range of 50–90°C, thermal treatment was found to have pronounced effect on colour change with increasing time, as represented in Figure 1(a). The colour development was found to be retarded throughout the temperature range of heat treatment, with a drastic decrease observed at high treatment time. Results showed that complete retardation of colour development was achieved with heat treatment at 90°C and holding time

of 120 sec. The regression lines for both level of time were found parallel to each other with similar reduction of colour development of 0.11 per unit temperature. Therefore, there was no interaction or quadratic effect between treatment factors (Figure 1-b). With increase in temperature, the reduction in colour development at high level (120 sec) of treatment time was found more than lower level of treatment time (60 sec). Such retardation in colour development was expected to be caused due to inactivation of oxidizing enzymes naturally present in the tender coconut water. Moreover, microbiocidal effect thermal treatment was also expected to brought out enhanced microbial sterility level, which results in less turbid coconut water even after prolonged storage under sealed condition. Further, the regression model fitting was performed and analysis of variance for the model was presented in table 2. The governing equation for colour development (in terms of yellowness) at different treatment combination was found to be, Yellowness = 5.461–2.163 (T, °C) – 1.10 (t, Sec) – 0.04 [(T, °C) x (t, Sec)] (R^2= 0.978). Result showing value nearly 2.8±0.9 was treated as no colour development, as it represents yellowness of fresh tender coconut water. Due to insignificant difference in a* value and dependency of L* on b*, only b* value was considered for experimentation, instead of considering ΔE.

3.3 Kinetics of colour change in tender coconut water.

A first order inactivation kinetic model (R^2=0.987) was applied to describe the experimental results for to explain the kinetics of colour changes in tender coconut water. The kinetic parameters are found to be, reaction rate constant (k) = 0.0045 sec^{-1} and decimal reduction time at 90°C (D_{90}) 221.811 sec. First order kinetic model was also applied on grapes (Fortea, M. I. Lpez-Miranda *et al.*, 2009) and red beet roots (Latorre, Mara E. Bonelli *et al.,* 2012), which was found suitable for explanation of colour based changes during storage. Matsui *et al.,* (2008) addressed inactivation kinetics of PPO and POD in tender coconut water by microwave processing, in which $D_{92.2°C}$ was reported as 52 sec for PPO and 16 sec for POD. They also highlighted the greater resistance of indigenous enzyme against inactivation treatments. However in this study the $D_{90.0°C}$ for colour preservation was found nearly four times higher, as per above mentioned literature. Such difference might be caused because, present study reports the overall colour preservation by thermal means, whereas Matsui *et al.,* (2008) reported the decimal reduction time for specific enzyme like PPO or POD by microwave processing.

Table 1 Physicochemical properties of tender coconut water

Parameters		Raw Tender Coconut Water
Volume of water extracted (mL)		188 ±31.990
Brix (Degree)		5.04 ± 0.608
Specific gravity		1.020 ± 0.002
Temperature (°C)		17.8 ± 1.054
pH		5.2 ± 1.054
Acidity %		0.15 ± 0.018
Brix/Acid		32.85 ± 5.234
Reducing sugar %		4.24 ± 0.587
Invert Sugar %		4.53 ± 0.471
Sucrose%		0.29 ± 0.198
Total sugar %		4.53±0.474
Total solid %		4.85 ± 0.565
Chloride %		ND
Ascorbic acid (mg) %		1.85± 0.035
Colour	L*	35.34 ± 0.987 (Brightness)
	a*	-0.57 ± 0.117(Greenness)
	b*	2.8 ± 0.909 (Yellowness)
Na^+ ppm		163.03 ± 28.720
K^+ ppm		3112 ± 253.520
Total phenolic (GAE eq mg/L)		31.63±560

Table 2 ANOVA for 2^2 experimental design and significant term determination

Source of variation	Sum of square	Degree of Freedom	Mean square	F-value	P-value
Model[1]	70.89	3	23.63	760.83	<0.001, Significant
Temperature	56.17	1	56.17	1808.47	<0.001, Significant
Time	14.70	1	14.70	473.31	<0.001, Significant
Temperature x Time	0.021	1	0.021	0.68	0.437, Not Significant
Pure error	0.25	8	0.031	-	-
Core total	71.14	11	-	-	-

Note: [1] The model is significant with a R^2 = 0.978

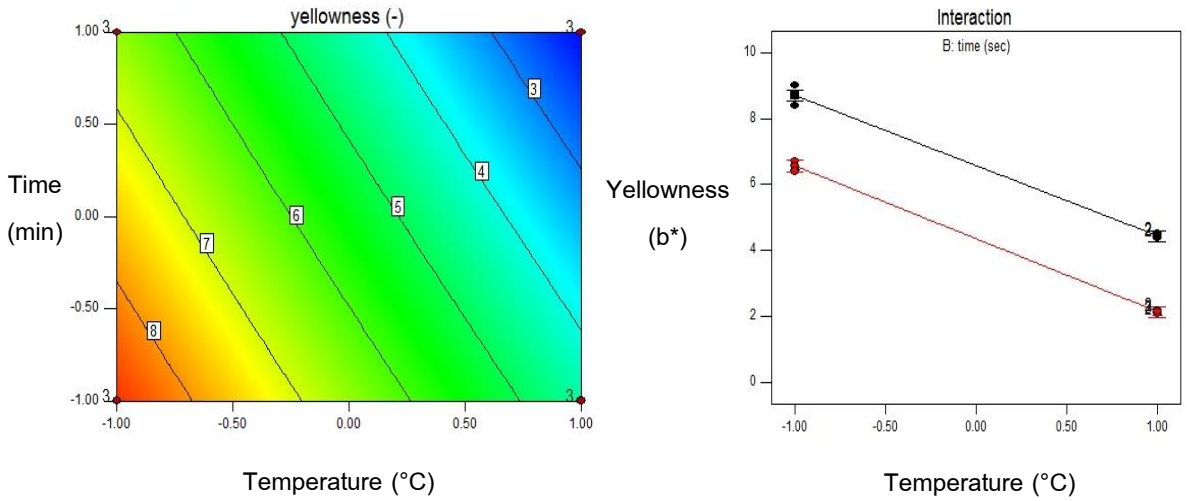

Figure 1 Effect of time (-1:60 sec, 0:90 sec, +1:120 sec) and temperature (-1:50°C, 0:70°C, +1:90°C) on colour development (A) Contour plot showing variation in yellowness (3-8), (B) Interaction plot

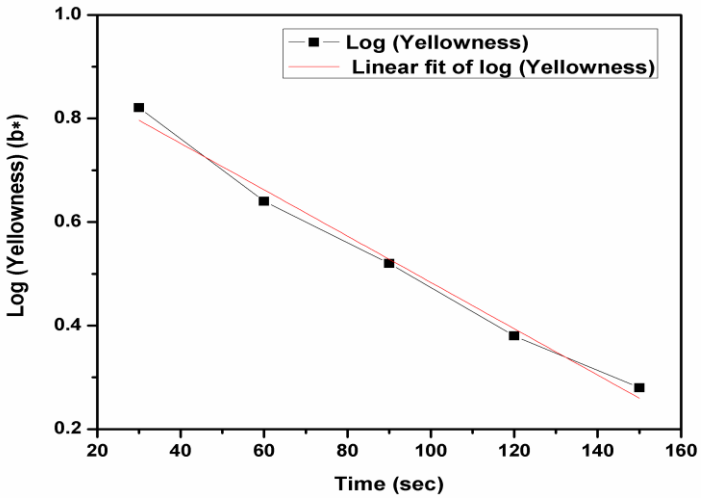

Figure 2 Deactivation kinetics of colour inactivation

4. Conclusion

A wide range of physicochemical properties along with colour and kinetics of colour inactivation was reported in the present study. Being one of the major sensory parameter; colour change during storage limits the shelf and marketability of tender coconut water. There is a significant change is colour was found upon storage of tender coconut water in room temperature, which refers to deterioration of organoleptic qualities. Findings from thermal treatment and inactivation kinetics reveal rate constant and decimal reduction time of 0.004 Sec^{-1} and 221.2 Sec, respectively. Treatment conditions found from this study suppose to render higher stability interms of natural colour of tender coconut water. Due to lack of scope, specific enzymatic inactivation percentage was not determined but the colour retardation in

colour change during storage was strongly considered as the outcome of enzyme inactivation. However, correlation between colour development and enzymatic activity should be formulated in future studies.

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