The Shelf life Estimation of Cold Sterilized Coconut Water

DOI: 10.18196/pt.2017.072.62-69

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ABSTRACT

Coconut water is well known due to its nutrient contents. Unfortunately, the properties such as flavor, aroma, and taste is easily altered, soon after it is extracted from the fruit by splitting the fruit in two and collecting the water in a clean container. The shelf-life of coconut water drink can be improved by eliminating the enzyme that causes the degredation of the quality, i.e. polyphenol oxidase and peroxidase enzyme. Heat treatment such as pasteurization and Ultra Heat Treatment may inhibit the growth of these enzymes although resulted in the loss of coconut water unique and desirable properties. Ultra-filtration membrane and ultraviolet are two potential cold-sterilization methods. The objective of this research was to estimate the shelf-life of coconut water after ultrafiltration membrane and ultraviolet sterilization. Cold-sterilized coconut water was stored at three temperatures, i.e. 8, 13 and 25 °C, using polyethylene bottles in individual sizes (250 ml). The shelf-life was estimated using Accelerated Storage Study method with Arrhenius equation. pH and total sugar contents were measured as critical parameters, and total plate count was also observed. This research concludee that the shelf-life of coconut water which cold sterilized without any food additives was etimated to be 15 days at 25 °C.

Keywords: Coconut water, Shelf-life estimation, Storage, Ultrafiltration membrane, Ultraviolet

ABSTRAK

Air kelapa terkenal akan berbagai kandungan zat gizinya. Namun, aroma dan rasa dari air kelapa mudah berubah, segera setelah dikeluarkan dari buahnya (dengan membelah dua buah dan menampung air dalam wadah bersih). Umur simpan minuman air kelapa dapat ditingkatkan dengan menghilangkan enzim penyebab perubahan kualitas, yaitu enzim polifenol oksidase dan peroksidase. Perlakuan panas seperti pasteurisasi dan Ultra Heat Treatment dapat menghambat pertumbuhan enzim-enzim ini meskipun akan menyebabkan hilangnya karakteristik air kelapa yang unik dan disukai. Membran ultrafiltrasi dan sinar ultraviolet adalah dua metode sterilisasi dingin yang potensial. Tujuan penelitian ini adalah untuk menduga umur simpan air kelapa setelah sterilisasi menggunakan membran ultrafiltrasi dan sinar ultraviolet. Air kelapa yang telah disterilisasi dingin kemudian disimpan pada tiga suhu, yaitu 8, 13 dan 25 °C, menggunakan botol polietilen berukuran individual (250 ml). Pendugaan umur simpan dilakukan menggunakan metode Accelerated Storage Study yaitu dengan persamaan Arrhenius. Nilai pH dan kadar gula total diukur sebagai parameter kritis, dan total plate count juga diamati. Sebagai kesimpulan, umur simpan air kelapa yang telah disterilisasi dingin dengan tanpa penambahan bahan tambahan apapun diduga 15 hari pada suhu 25 °C.

Kata kunci: Air kelapa, Pendugaan umur simpan, Penyimpanan, Membran ultrafiltrasi, Ultraviolet

INTRODUCTION

Coconut is well known due to its many benefits from every part of the coconut. Technology development had resulted in various products from coconut, giving considerable added values. One of underutilized coconut parts is coconut water. Most of the coconut water is unused and discarded into the environment, especially those from copra and coconut oil industry. The main obstacle to the development of coconut water product is its easily altered properties. Immediately after contact with air, coconut water will lose almost all its unique organoleptic properties and starts fermenting. Thus, in just a few hours after extracted from the fruit (usually by splitting the fruit in two), coconut water will turn turbid, yellowish, sour, and bad aroma. These alterations were caused by the existence of oxidase enzymes, i.e. polyphenol oxidase and peroxidase (Duarte et al., 2002; Magalhaes et al., 2005) and the microbe contamination (Magalhaes et al., 2005).

The shelf-life of coconut water isotonic drink can be improved by ensuring the elimination of the causes of its quality degradation. There are some methods can be conducted to preserve coconut water. Most of the commercial production of coconut water based drinks use pasteurization and *Ultra-High-Temperature* technology. However, the processing using high temperature may cause the loss of nutritional value and the unique aroma and flavor of coconut water (Haynes et al., 2004).

Coconut water processing without high temperature had been introduced by FAO (2000), using microfiltration membrane. This process was then further developed by Kailaku et al. (2006) where after microfiltration, ultrafiltration membrane was used. Ultrafiltration is a separation process using a membrane, working in the pressure difference principal. Ultrafiltration and pasteurization process had been shown to have the same effectiveness in reducing the enzymes activities in coconut water (Nakano et al., 2011). However, there was still doubt in its effectivity in reducing microorganism activities. Ultraviolet technology is a becoming more commonly used in purification and sterilization various products such as water, fruit juices, etc. (Falguera et al., 2011).

The combination of ultrafiltration and ultraviolet technology may increase the inactivation of microorganisms responsible for degrading the quality of coconut water. Both technologies need low energy intake and were expected to be able to maintain the nutritional and chemical composition along with the organoleptic properties of coconut water. The objective of this research was to estimate the shelf-life of coconut water after processing with ultrafiltration membrane and ultraviolet sterilization.

MATERIAL AND METHODS

The production, characterization, and analysis of coconut water drink were conducted at Research and Development Laboratory, Indonesian Center for Agricultural Postharvest Research and Development, Bogor, Indonesia. The flow chart of coconut water drink production using ultrafiltration membrane and ultraviolet sterilization was presented in Figure 1.

The development of coconut water drink did not include formulation stage. The material used in this study was only fresh coconut water, without any addition of food additives, in order to obtain the influence information of ultrafiltration and ultraviolet processing without factors of other ingredients or treatments. The coconut was Genjah variety and was collected at the age of 8-9 months from local community plantation in Bogor, Indonesia.

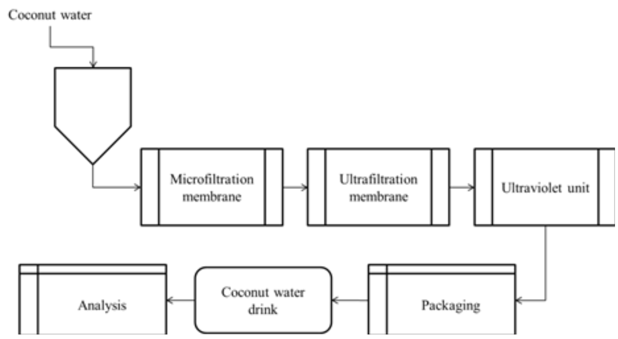

Figure 1. Flow chart of the cold sterilization of coconut water

Fresh coconut water was immediately cold-sterilized by filtering through microfiltration (1000 nm pore size diameter) and ultrafiltration (50 nm pore size diameter) membranes followed by passing through the ultraviolet tube. The ultrafiltration membrane was operated at maximum pressure of 3 bar. UV tube dimension was 64 x 340 mm in diameter and length, respectively. The flow rate of the product through the tube was 1 litre/sec. The sterilized coconut water flowed from UV tube directly into a container through a rubber tube.

The product were analyzed for its physicochemical properties and nutritional composition, i.e. pH (Indonesian National Standard

SNI 06-6989.11-2004), clarity (Spectrophotometer), colour (Chromameter), total soluble solid (AOAC, 2005), total sugar content (Sulaeman et al., 1995 in Riyana, 2008), sucrose, fructose and glucose content (Indonesian National Standard SNI 01-2892-1992), vitamin B1 and B6 content (Hidayati, 1992), vitamin C (High Performance Liquid Chromatography) and K, Na and Mg content (APHA, 1998 in Roji, 2006).

Critical parameters (pH and total sugar content) were observed nine times in 19 days. Coconut water drink was stored in temperature controlled room using three different temperatures, i.e. 8, 13 and 25^{0}C. Samples were bottled in clear polyethylene plastic bottle in individual size (250 ml).

Data obtained from analysis where processed based on Arrhenius method. The calculation of shelf-life was done using equation 1 (Sukasih *et. al.* 2007).

$$ts = [\ln(No - Nt)]/K_T \quad (1)$$

where: ts = duration of storage

No = value of quality parameter on t_0 (the beginning of storage)

Nt = value of quality parameter after t duration of (critical limit)

K_T = value of K in storage temperature T

RESULTS AND DISCUSSION

Characterization of cold-sterilized coconut water

The composition of nutrition content and physicochemical properties of cold-sterilized coconut water as shown in Table 1. The appearance of fresh coconut water and cold-sterilized coconut water as seen in Figure 2. Kailaku et al., 2016 reported that the differentiation analysis of cold-sterilized coconut water and fresh coconut water showed that most of the coconut water nutritional composition was not different with that of fresh coconut water. The difference was only observed in total sugar content, although sucrose, fructose, and glucose content were not significantly different. The physical characteristics were also mostly unaffected by the cold-sterilization, except for the clarity and color parameters (L* dan b*). The theses stated that an amount of sugar content in coconut water may be filtered by ultrafiltration membrane, causing the small decrease of total sugar content (p = 0.049).

Table 1. The characteristics of cold-sterilized coconut water compared with fresh coconut water

Characteristics	Fresh Coconut Water	Cold-sterilized Coconut Water	p-value
pH	5.60	5.40	0.126
Total sugar (%)	6.13	6.06	0.049*
Sucrose (%)	0.64	0.62	0.758
Fructose (%)	2.71	2.63	0.537
Glucose (%)	2.72	2.70	0.500
Potassium (mg/kg)	1840.54	1736.46	0.272
Sodium (mg/kg)	20.73	14.17	0.174
Magnesium (mg/kg)	86.54	75.30	0.232
Vitamin B1 (mg/100ml)	11.97	11.85	0.053
Vitamin B6 (mg/100ml)	0.033	0.029	0.455
Clarity (% to water)	97.4	89.5	0.001*
Colour			
L	101.78	97.05	0.000
a	-0.24	-0.18	0.390
b	-0.06	0.58	0.002*
Total plate count (cfu/ml)	1.86x102	1.08x101	na

*significantly different at alpha=0.05, na=not available

Figure 2. The appearance of fresh coconut water (1) and cold-sterilized coconut water (2)

Shelf-life estimation

The estimation of shelf-life is very important in commercialization of food product, especially a newly developed food product. Food shelf-life is a period of time after production where a product is able to maintain acceptability, both in sensory and nutritional, and safe for consumption (Ahrne *et* al. 1996). The shelf-life of a product can be estimated using various methods, one of which is using kinetics model such as Arrhenius model (Maria and Peleg 2007).

Arrhenius method uses acceleration (*Accelerated Storage Study*/ASS) and implements reaction kinetics study with the aid of Arrhenius equation. The principal is to store a food product at a certain temperature, in order to cause quality deterioration of its critical parameters due to the influence of heat. This method allows the research on storage to use three different temperatures to predict the shelf-life of different storage conditions (Hough *et al.* 2006).

The first step of ASS is the determination of critical parameters. Critical parameters used in this study were pH and total sugar content. These parameters were selected based on the consideration that the pH of coconut water is easily altered during storage, while total sugar content is one of the important sensory parameters that determine the acceptability of coconut water. The changes of pH value and total sugar content of cold-sterilized coconut water are presented in Figure 3 and Figure 4.

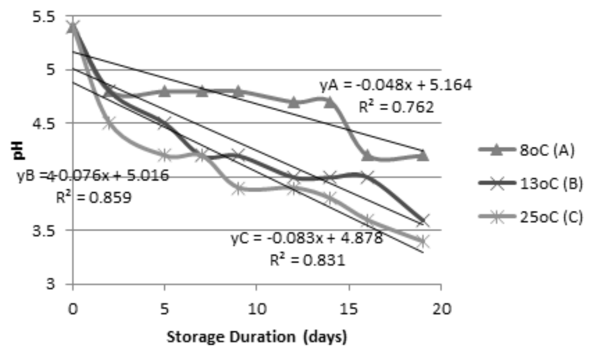

Figure 3. The pH degradation of cold-sterilized coconut water during storage

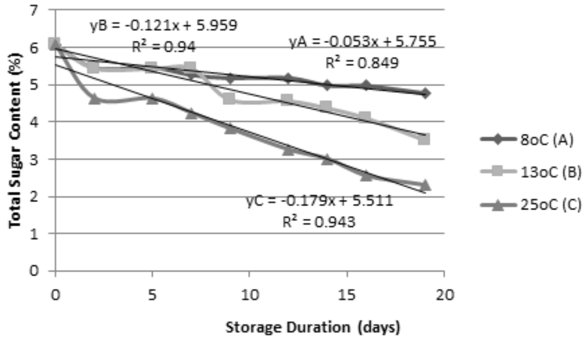

Figure 4. The total sugar content degradation of cold-sterilized coconut water during storage

Figure 3 showed that the decrease of pH was influenced by the higher temperature. The decrease of pH observed in this research (1.9 points at 8^{o}C) was higher compared to that observed by Awua *et. al.* (2012) where the pH of fresh coconut water decreased by 2.3 points after 30 days of storage at 4^{o}C. The decrease of pH may occur due to the formation of phenol radicals and phenol oxides, which may also cause the formation of yellowish color of the product (Awua *et. al.* 2012).

Total sugar content also experienced a declining trend during storage at all temperature, as shown in Figure 4. The decrease od total sugar content may be caused by the utilization of sugar and other simple carbohydrate in the formation of unsoluble matters, which are the essential substance in the coconut endosperm (Awua *et. al.*, 2012).

The quality deterioration of both critical parameters was calculated by determining the slope, intercept and the correlation on reaction order 0 and ordo 1 (Tabel 2 and 3). The determination of reaction order is a means to predict the tendency of quality deterioration (Sukasih *et al.* 2007).

Table 2. The value of the slope, intercept, and correlation coefficient in reaction order 0 and 1 and the linear equation of pH of coconut water drink

		Temperature		
		8^0C	13^0C	25^0C
Order 0	R square	0.76198	0.85903	0.83134
	Intercept	5.16466	5.01687	4.87871
	Slope	-0.04860	-0.07680	-0.08340
Order 1	R square	0.76663	0.88757	0.87769
	Intercept	1.64391	1.61509	1.58695
	Slope	-0.01030	-0.01750	-0.01980
lnK (order 1)		-4.57120	-4.04780	-3.92390
T (Kelvin)		281	286	298
1/T (Kelvin)		0.00356	0.0035	0.00336
Linear equation		Y = -2795.2X + 5.51908 R^2 = 0.71592		

Table 3. The value of the slope, intercept, and correlation coefficient in reaction order 0 and 1 and the linear equation of total sugar content of coconut water drink

		Temperature		
		8^0C	13^0C	25^0C
Order 0	R square	0.84897	0.93997	0.94359
	Intercept	5.75566	5.95916	5.51124
	Slope	-0.05346	-0.12158	-0.17954
Order 1	R square	0.87119	0.93320	0.97211
	Intercept	1.75093	1.80140	1.74724
	Slope	-0.01003	-0.02578	-0.04777
lnK (order 1)		-4.60231	-2.10721	-3.04137
T (Kelvin)		281	286	298
1/T (Kelvin)		0.00356	0.0035	0.00336
Linear equation		Y = -5247.25X + 14.95929 R^2 = 0.18744		

Table 2 and 3 show that the correlation (R^2) of reaction order 1 is higher than reaction order 0, for pH parameter and total sugar content. Lee and Krochta (2002) stated that the quality deterioration reaction of food materials mostly occurs at order 0 and 1. The kinetic reaction of quality deterioration, oxidative color change, rancidity, microbial growth, and vitamin degradation are the examples of order 1 kinetic reactions. Meanwhile, the order 0 reaction are enzymatic destruction, enzymatic browning, and oxidation.

After the determination of reaction order, shelf-life estimated was calculated using Arrhenius equation. Arrhenius equation obtained by plotting the value of ln k with 1/T, where k was slope value as deterioration value of quality during storage and T was temperature.

The initial quality values were used in the calculation of shelf-life estimation. The analysis showed that pH of coconut water sample was 5.4 and the total sugar content was 6.06 %. The coconut drink produced in this study was designed to be natural isotonic drink. Therefore the critical limits were determined based on Indonesian National Standard of Isotonic Drink, i.e. 4 for pH and 5 % for total sugar content.

The Arrhenius equation of the samples in the analysis of parameter pH was Ln K = LnK = 5.519082 – 2795.2 (1/T), where if it was stored in temperature 8^0C it would generate the value of Ln K=--4.42807 or K=0.01194. This means that there will be 0.01194 unit decrease of pH per day. According to the calculation using equation 1 (Sukasih *et al.* 2007), it was estimated that the shelf-life of coconut water drink were 28 days in 8^0C storage, 23 days in 13^0C storage and 15 days in 25^0C storage (Table 4).

Table 4. The estimation of shelf-life of cold-sterilized coconut water based on pH

	Temperature		
	8^0C	13^0C	25^0C
Arrhenius equation	LnK = 5.519082 – 2795.2 (1/T)		
LnK	-4.42807	-4.25417	-3.86062
K	0.01194	0.0142	0.0211
Initial quality (No)	5.4	5.4	5.4
Critical limit (Nt)	4	4	4
Shelf-life (days)	28.1862	23.6871	15.9806

In the analysis of total sugar content, equation Arrhenius Ln K = LnK = 14.95929 – 5247.25 (1/T), so that storage in 8^0C will generate the value of Ln K=-3.71421 or K=0.02437.

This means that there will be 0.02437 unit decrease of total sugar content per day. Based on the calculation using equation 1 on total sugar content parameter, the estimated shelf-life of coconut water drink were 29 days (8^{0}C), 21 days (13^{0}C) and 10 days (25^{0}C) (Table 5).

Table 5. The estimation of shelf-life of cold-sterilized coconut water based on total sugar content

	Temperature		
	8^{0}C	13^{0}C	25^{0}C
Arrhenius equation	LnK = 14.95929 – 5247.25 (1/T)		
LnK	-3.71421	-3.38775	-2.64894
K	0.02437	0.03378	0.070726
Initial quality (No)	6.06	6.06	6.06
Critical limit (Nt)	5	5	5
Shelf-life (days)	29.6498	21.3915	10.2184

The calculation of shelf-life estimation may give different results among different critical parameters (Sukasih *et al.* 2007). The estimated shelf-life using pH as a critical parameter was different with that of total sugar content. The recommendation of shelf-life should be determined based on the shorter shelf-life, considering the safety of the product (Koswara dan Kusnandar 2004), or based on the higher correlation value (Sukasih *et al.* 2007).

According to the aforementioned considerations, it was determined that the calculation of shelf-life estimation using pH was to be used. When stored in the room temperature (25^{0}C), the shelf-life of coconut water drink is 15 days. This result is shorter compared to the results in Kailaku *et al.* (2006) and Naozuka (2004). Kailaku *et al.* (2006) studied the shelf-life of coconut water drink produced using ultrafiltration membrane and showed that the product was still in good quality after 3 months storage in the refrigerator. However, the product was formulated with the addition of food additives such as sodium carbonate and citric acid, which acted as preservative and acidity controller agents. Naozuka (2004) conducted research using the freezing method, resulted in the shelf-life of coconut water of 30 days. Unfortunately, there were physicochemical, and enzymatic degradation observed after the thawing process.

The *Total Plate Count* analysis of the product showed the total microbes of 1.08x10^1 CFU/ml, while fresh coconut water contained 1.86x10^2 CFU/ml total microbes. The Indonesian National Standard required the maximum total microbes of 2x10^2 CFU/ml. Unprocessed coconut water had more than 10^{10} CFU/ml total microbes after 19 days storage at any temperature. Meanwhile, the total microbes of cold-sterilized coconut water were 1.94x10^2 CFU/ml (8^{0}C), 2.50x10^2 CFU/ml (13^{0}C) and 4.70x10^2 CFU/ml (25^{0}C) after 19 days storage. This result should be further studied in order to identify the type of growing microbes. Not only to study if there were undesired microbes grows, e.g., *E. coli*, but also to confirm the possibility of using the pH and nutritional composition of coconut water as a medium of useful bacteria such as *Acetobacter xylinum* and *Lactobacillus sp*.

Although the shelf-life obtained in this study was fairly long compared to that of unprocessed coconut water, this result is not enough for an industrial purpose such as distribution and transportation, which need more extended shelf-life. However, scaled up production is expected to have a better result, considering various weak aspects that may interfere the quality assurance of laboratory scale in this study, e.g., the less than optimum processing condition of ultrafiltration membrane and the non-fully aseptic processing condition. Production and distribution using cold chain system are expected to have a far better result.

Moreover, Prades *et al.* (2012) reviewed numerous research reports on the processing and the shelf-life of coconut water and concluded that thermal treatments i.e. pasteurization, sterilization, and non-thermal treatments i.e. microfiltration were not enough to obtain an extended shelf-life of coconut water without the addition of any food additives. An effective result may be obtained by adding molecules e.g., nisin, ascorbic acid, citric acid, and sodium metabisulfite. Studies using those materials succeeded in maintaining the quality of pasteurized coconut water for 2-3 months at room temperature or refrigerator.

CONCLUSIONS

Cold-sterilized coconut water obtained from processing using ultrafiltration membrane and ultraviolet, without the addition of food additives experienced the decrease of pH and total sugar content during storage. The estimation of shelf-life using Accelerated Storage Study with Arrhenius equation, based on pH as critical parameter showed that the product's shelf-life was 15 days at 25°C. This result was better than the shelf-life of unprocessed coconut water, but not adequate for industrial scale and distribution purpose.

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